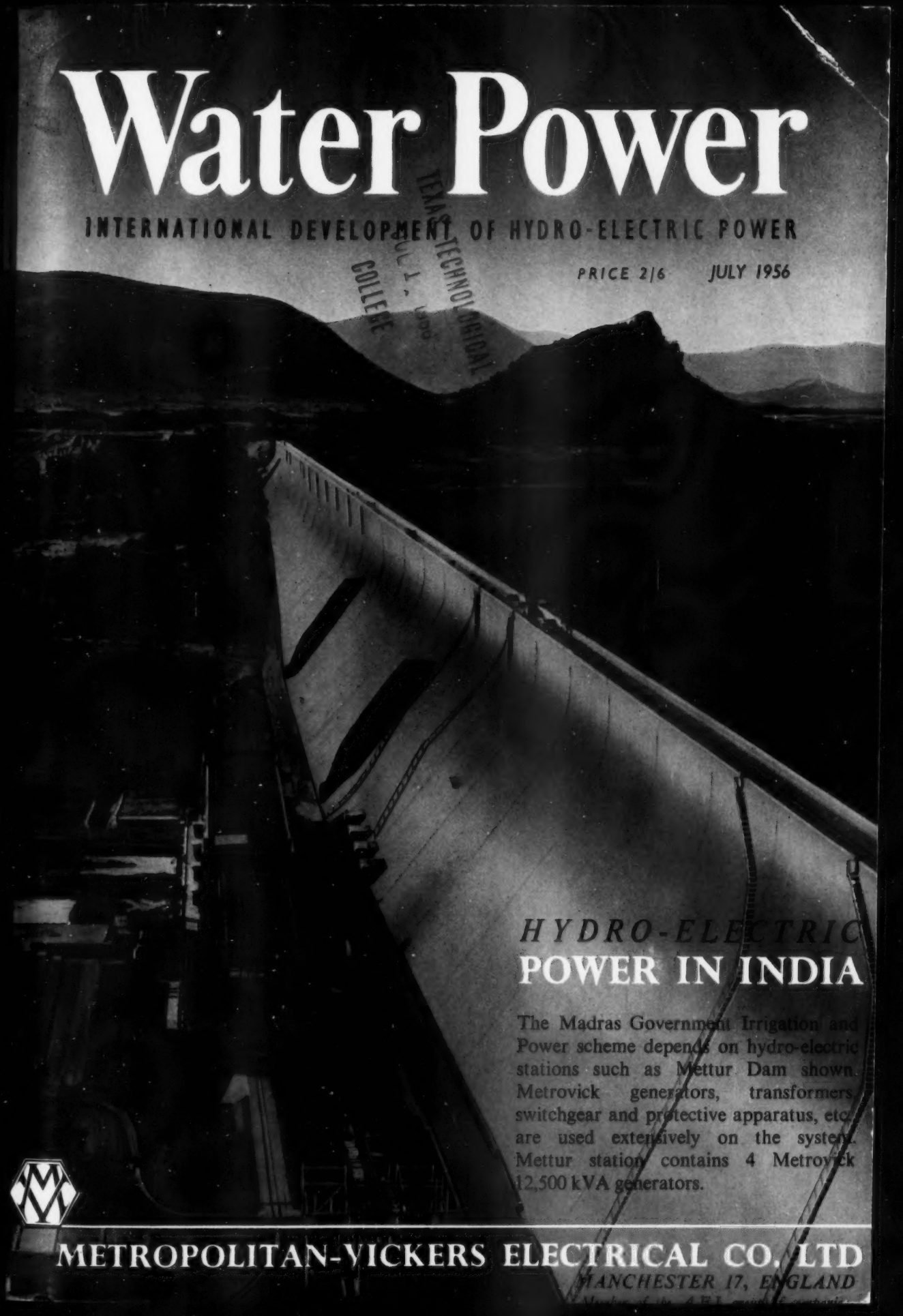
Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 JULY 1956

TEXAS TECHNOLOGICAL COLLEGE

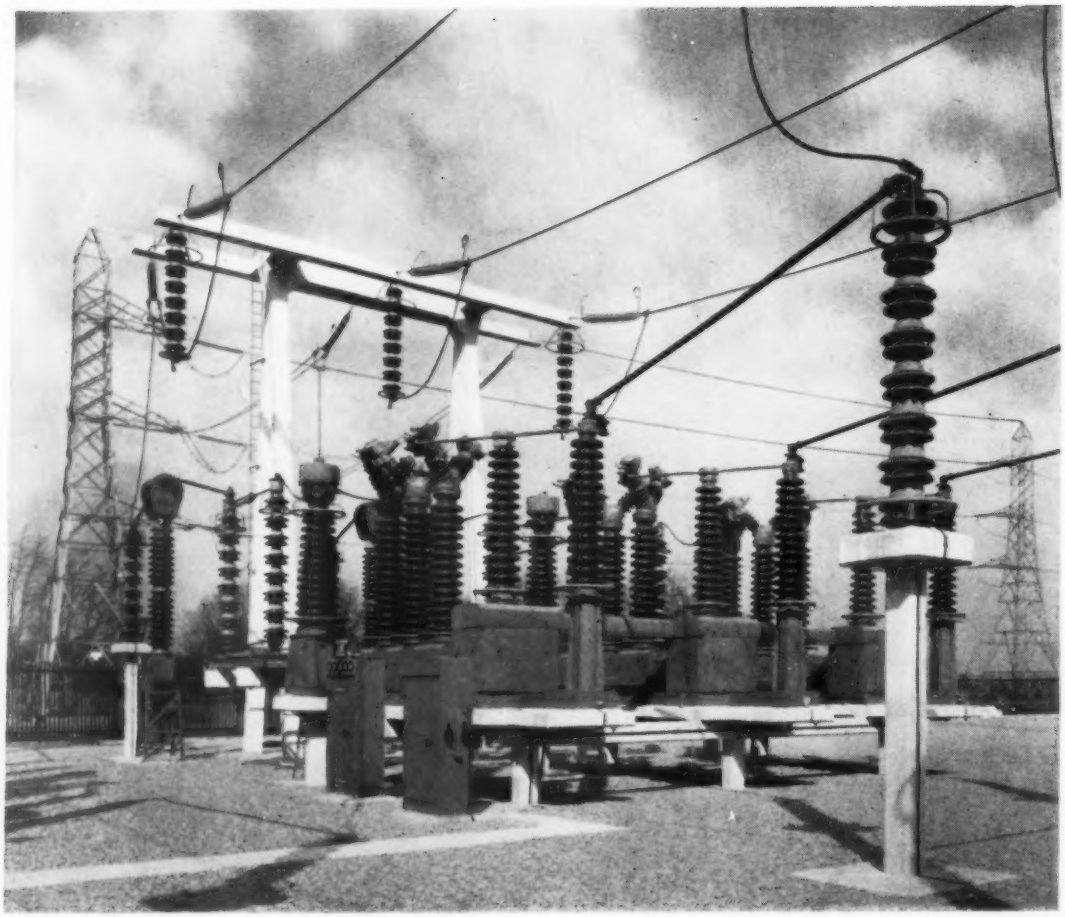


HYDRO-ELECTRIC POWER IN INDIA

The Madras Government Irrigation and Power scheme depends on hydro-electric stations such as Mettur Dam shown. Metrovick generators, transformers, switchgear and protective apparatus, etc., are used extensively on the system. Mettur station contains 4 Metrovick 12,500 kVA generators.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD

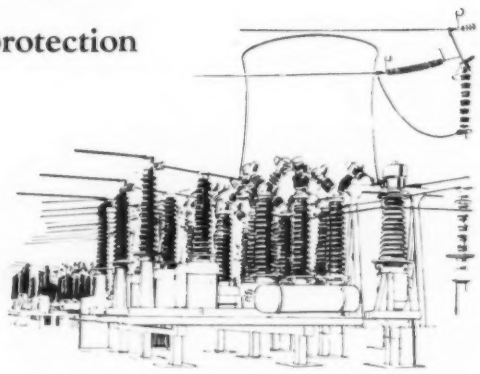
MANCHESTER 17, ENGLAND



Photograph by courtesy of the C.E.A., East Midlands Division

Consulting Engineers : Merz and McLellan

At Drakelow, the largest 275-kV installation in Great Britain, Reyrolle air-blast switchgear is used with telephase and mono-bias protection

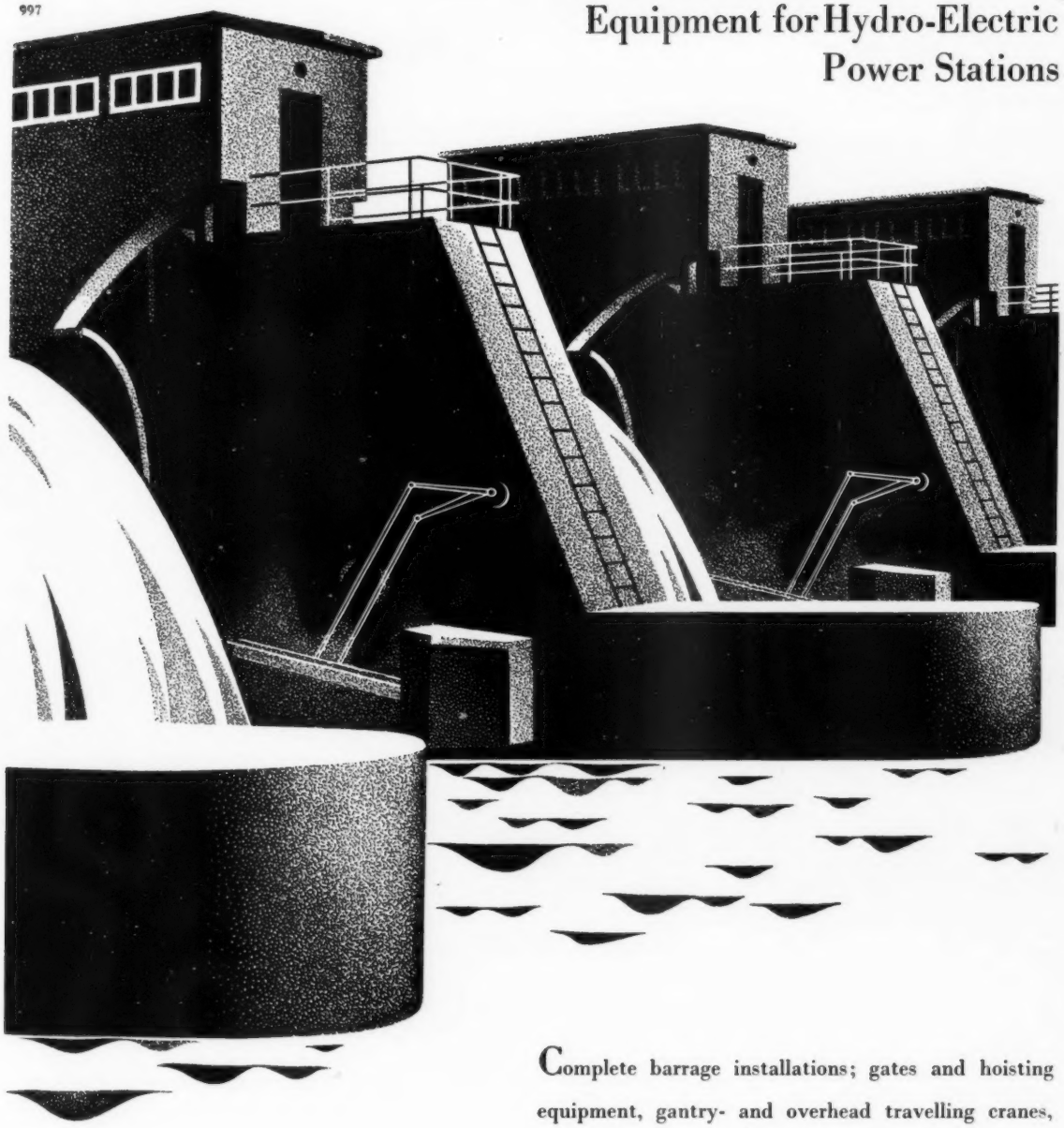


Reyrolle

A. REYROLLE & COMPANY LIMITED HEBBURN, COUNTY DURHAM, ENGLAND

TK
1081
W5
U618.
J1\Dec

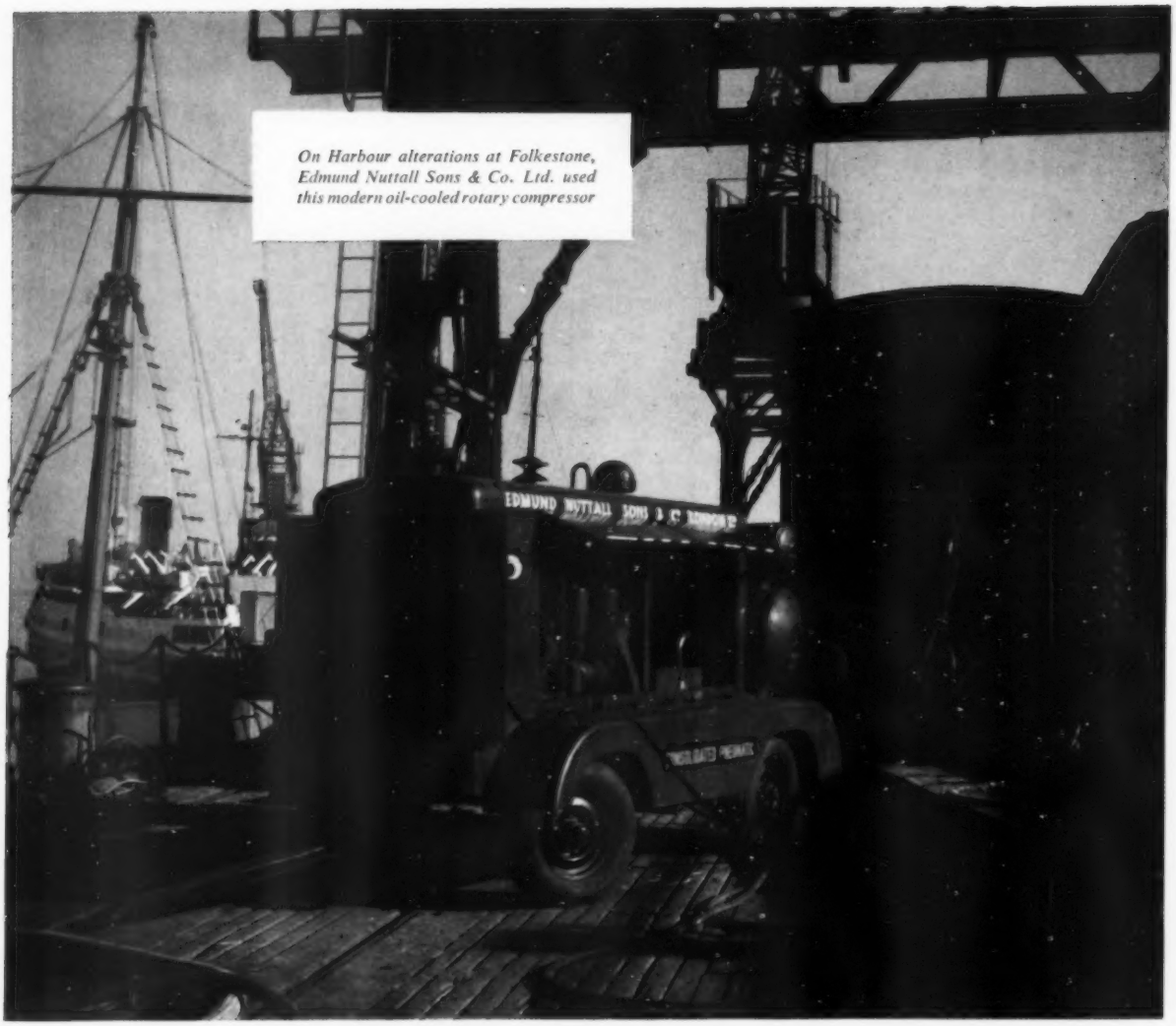
Equipment for Hydro-Electric Power Stations



DE ROLL

Louis de Roll, Ironworks Ltd.
Works at Gerlafingen, Klus, Choindez, Rondez, Olten, Berne (Switzerland)

Complete barrage installations; gates and hoisting equipment, gantry- and overhead travelling cranes, trash screen cleaning machinery; sluice gates; control valves for high pressure conduits; automatic safety organs for pipe lines; discharge regulating valves, rotary valves with rotary-piston servomotors, needle valves, butterfly valves, high pressure fittings, piping systems for oil and cooling water plant; funicular and aerial cableways for passenger and goods transport; building machinery for dam-building work.



On Harbour alterations at Folkestone, Edmund Nuttall Sons & Co. Ltd. used this modern oil-cooled rotary compressor

Because it represents a revolutionary advance in design . . .

more and more contractors are turning to the CP Power-Vane rotary compressor. Now, a simple two-stage vane type rotary compressor replaces those moving parts most subject to trouble. There are no pistons, valves, crankshaft or clutch. The entire unit runs in oil and is oil cooled. Other desirable features which put the CP Power Vane well to the fore include fully automatic safety devices, centralised instrument panel, non-detachable folding side shutters and radiator doors. The Power-Vane is available in a range with outputs of 125, 175, 210, 365 and 600 cu. ft. Certainly this is something every Plant Engineer should know about. Ask for Catalogue 58c.

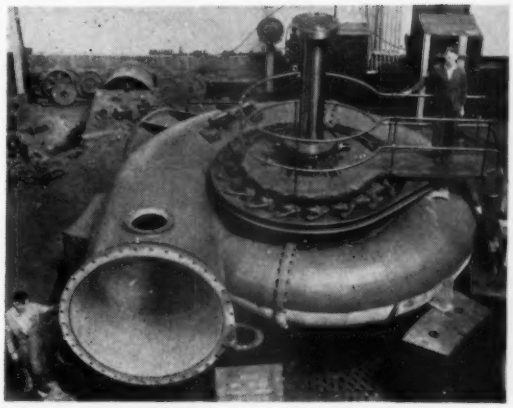
POWER VANE

ROTARY COMPRESSORS

MANUFACTURED BY CONSOLIDATED PNEUMATIC TOOL CO. LTD., 232 DAWES ROAD, LONDON, S.W.6

CP80

6 1957
CH



the Wairpori scheme

The scheme consists of [illegible] developing [illegible] power of a single river. [illegible] its inception Boving have supplied turbines in each station, nine turbines having been supplied, culminating in those for stations 3 and 4 commissioned in 1955. Each of these has a single Vertical Francis turbine of 8,700 h.p. and 10,000 h.p. respectively

Boving

& COMPANY LIMITED

WATER POWER ENGINEERS

56 KINGSWAY LONDON WC

BROWN BOVERI

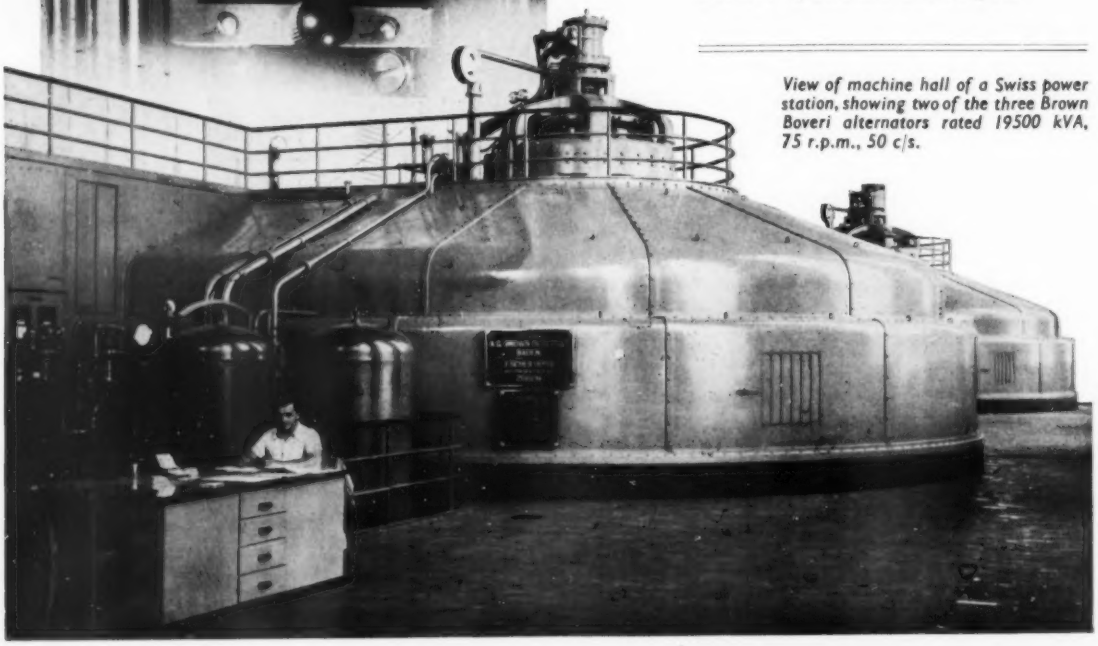
Are your generators reliably protected?

Will they be de-energised immediately a fault occurs in the windings?

Brown Boveri
generator protecting equipment
reliably detects the different types of faults and will effectively safeguard your machines

Hundreds of power stations are equipped with our protective gear

Let our specialists advise you



View of machine hall of a Swiss power station, showing two of the three Brown Boveri alternators rated 19500 kVA, 75 r.p.m., 50 c/s.

BROWN, BOVERI & CO., LTD., BADEN (SWITZERLAND)

For faster penetration, greater reliability...

Specify the Silver Three every time. Designed for use with the labour-saving Airleg, it drills faster than any other machine of its weight and most heavier ones. That's been proved in actual operation. If you're out to raise productivity to a maximum, there's nothing to touch the Silver Three.

BORE:	3″ (76 mm)
STROKE:	1 15/16″ (49 mm)
WEIGHT DRY:	47 lb. (21 kg)
WEIGHT WET:	49 lb. (22 kg)

...the record breaking Silver Three

Holman

ROCK DRILLS
AIR COMPRESSORS
PNEUMATIC TOOLS

HOLMAN BROS. LTD., CAMBORNE, ENGLAND

Telephone: Camborne 2275 (10 lines)
Telegrams: Airdrill, Camborne
London Office: 44 Brook Street, W.1 Hyde Park 9444

HH7

COURTESY OF NORTH OF SCOTLAND HYDRO-ELECTRIC AUTHORITY AND MESSRS. TAYLOR WOODROW CONSTRUCTION LTD.

ADAPTABILITY OF BAILEY BRIDGE UNITS

COURTESY OF RIXBURGH HYDRO-ELECTRIC AUTHORITY, NEW ZEALAND.

COURTESY OF THE MERSEY RIVER BOARD, CHESHIRE.

COURTESY OF STATE OF VERMONT HIGHWAYS DEPARTMENT, U.S.A.

COURTESY OF MESSRS. DEMOLITION AND CONSTRUCTION CO. LTD.

There is no limit to the number of structures that can be built with Bailey Bridge Units—All types of Bridges, falsework, scaffolding, piers, buildings, gantries, runways etc.—in fact new components are constantly being designed to meet the requirements of civil engineers all over the world.

Very often it is possible to economise on known standard constructions, and we strongly recommend you to submit problems to our engineers so that the most economical solution can be employed.

We are interested in your particular problem, and are prepared to fabricate bridges and structures to your own individual designs.

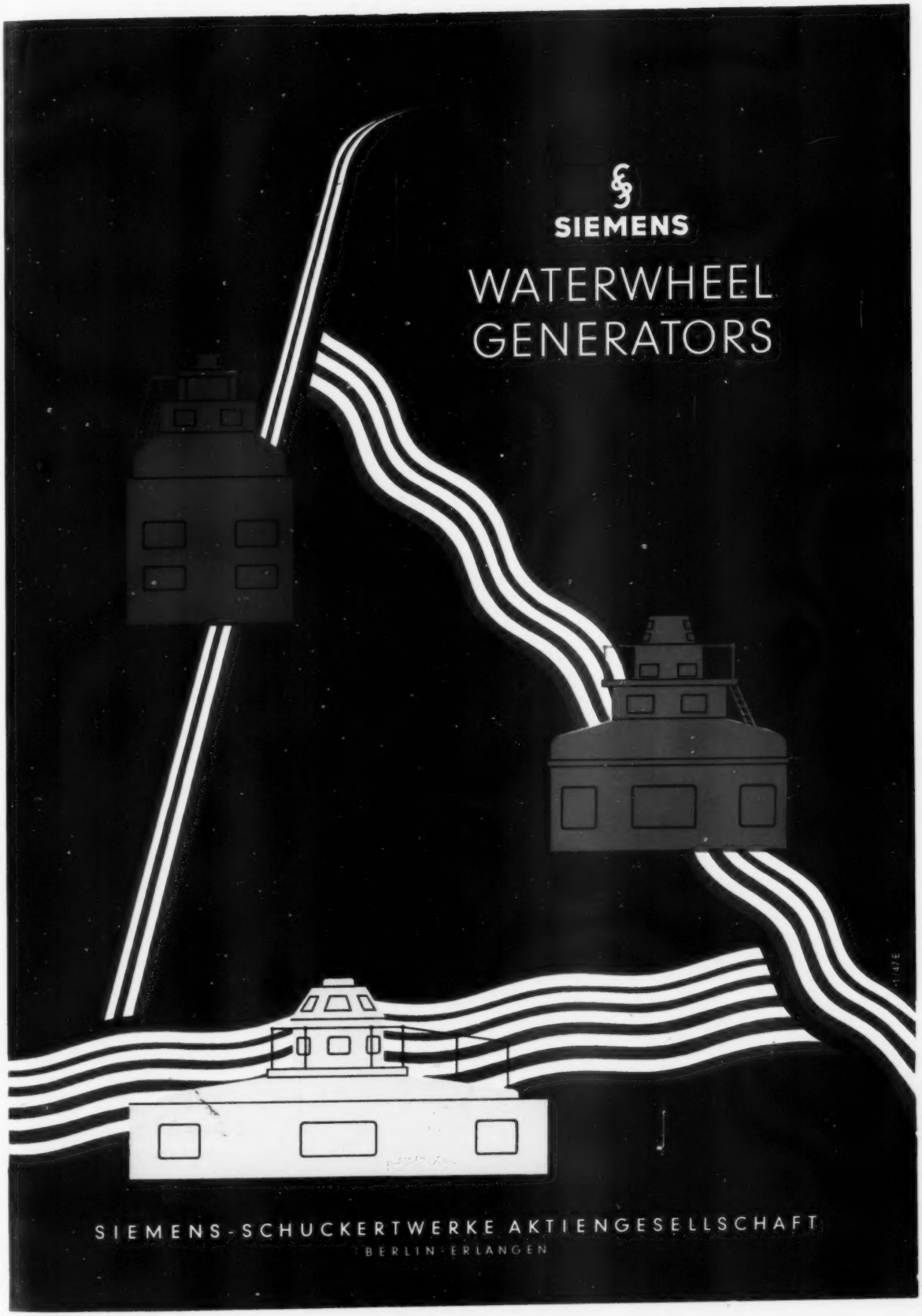
THOS. STOREY (Engineers) **LTD.**

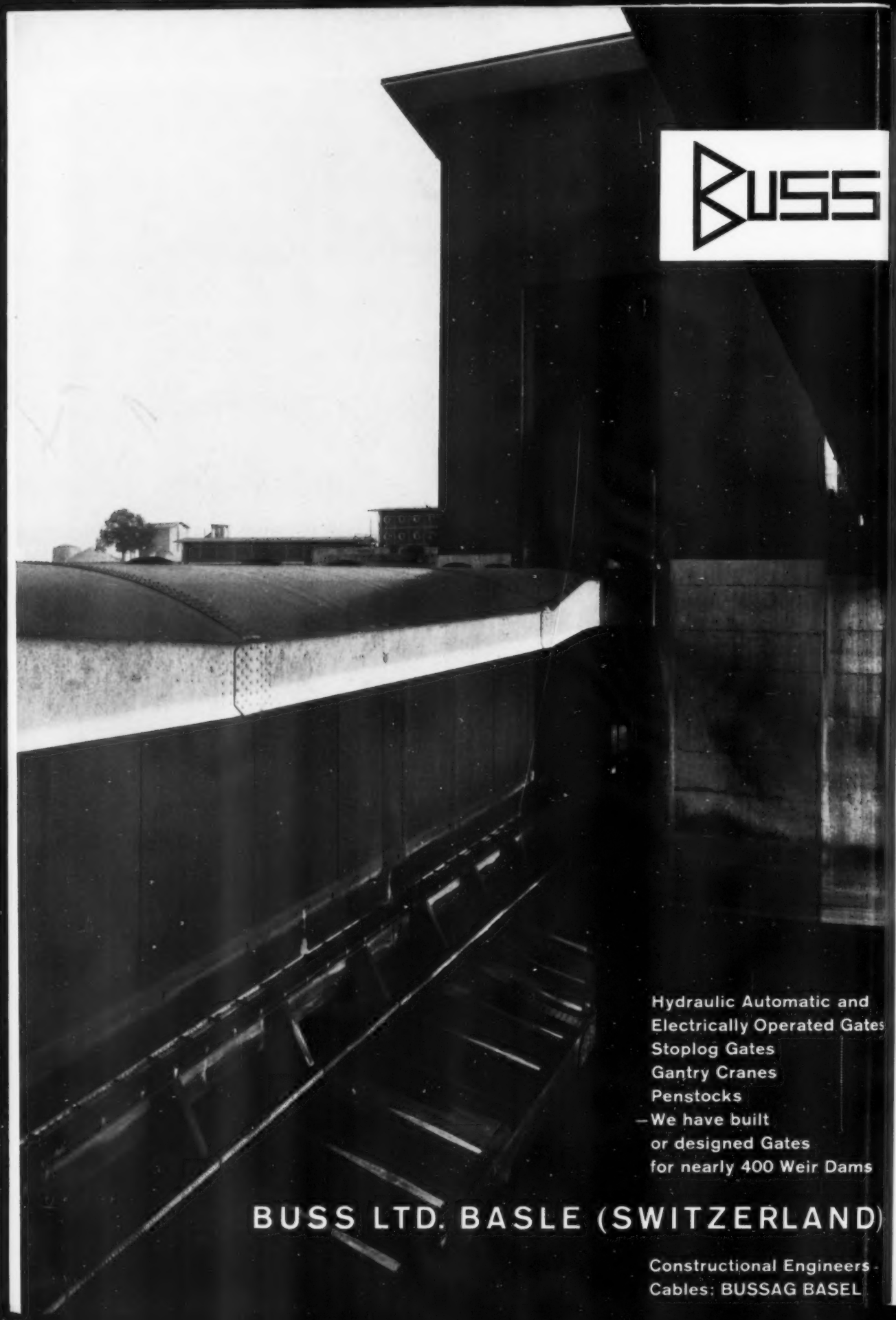
WORLD LICENSEES FOR THE MANUFACTURE & SALE OF BAILEY BRIDGING

STOCKPORT & LONDON ENGLAND

ENQUIRIES TO LONDON SALES OFFICE · 6 VICTORIA STREET · WESTMINSTER SW1

TELEPHONE: ABBEY 7391-2 TELEGRAM: MICROFAB SOWEST LONDON CABLES: MICROFAB LONDON

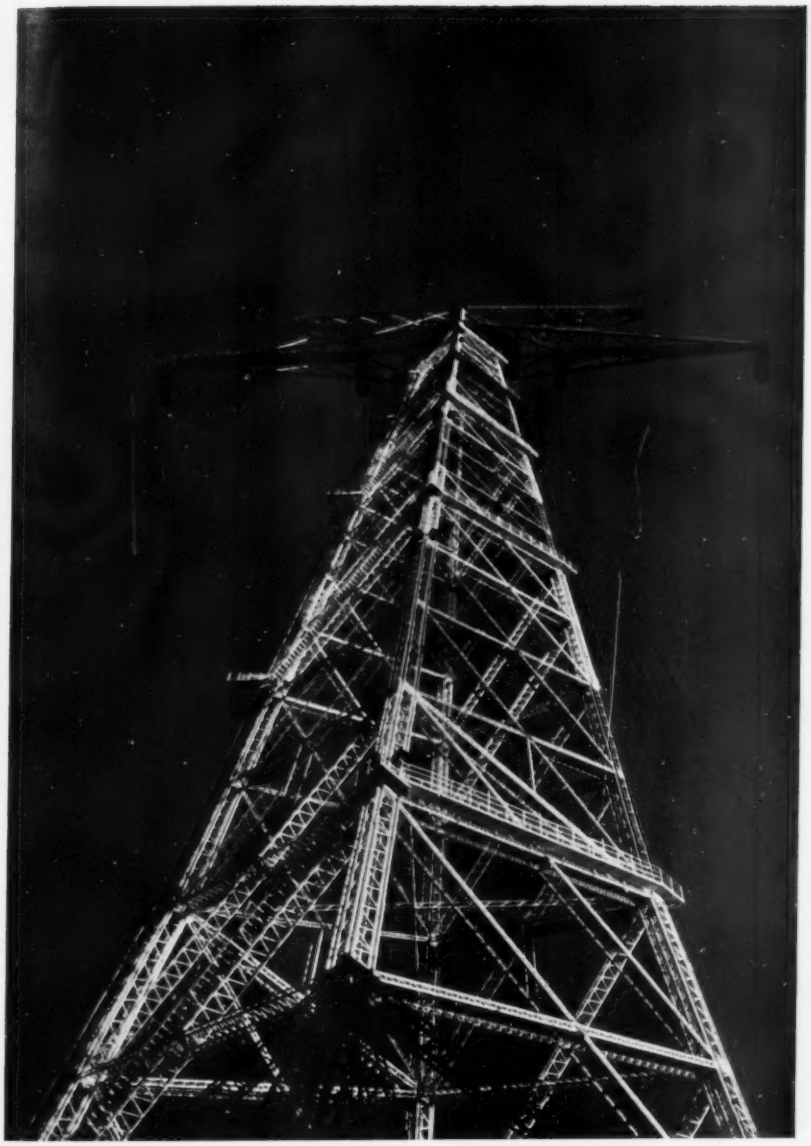

SIEMENS
WATERWHEEL
GENERATORS
SIEMENS-SCHUCKERTWERKE AKTIENGESELLSCHAFT
BERLIN-ERLANGEN



Hydraulic Automatic and
Electrically Operated Gates
Stoplog Gates
Gantry Cranes
Penstocks
—We have built
or designed Gates
for nearly 400 Weir Dams

BUSS LTD. BASLE (SWITZERLAND)

Constructional Engineers
Cables: BUSSAG BASEL



30 years
of experience in
Designing
Supplying and
Erecting

Power transmission lines

Railway, tramway and trolley-bus contact lines

Overhead and cable telegraph and telephone lines

Electric light and signal installations

Lattice towers for power lines and substation structures

Steel structures for industrial buildings, warehouses and radio towers

Centerings for bridges and frameworks of all kinds

Galvanized fittings for electric lines and substations

Erection equipment

Have established a leadership

Standing guard across the legendary Messina Straits two steel giants stretch their 250′ crossarms to support the 12,000′ span.*

DESIGN, FABRICATION & ERECTION BY SAE-MILAN

**Height 735′, weight 500 tons.*

EST. ELETTRIFICAZIONE SAE MILANO 1926

SOCIETÀ ANONIMA ELETTRIFICAZIONE S.p.A.

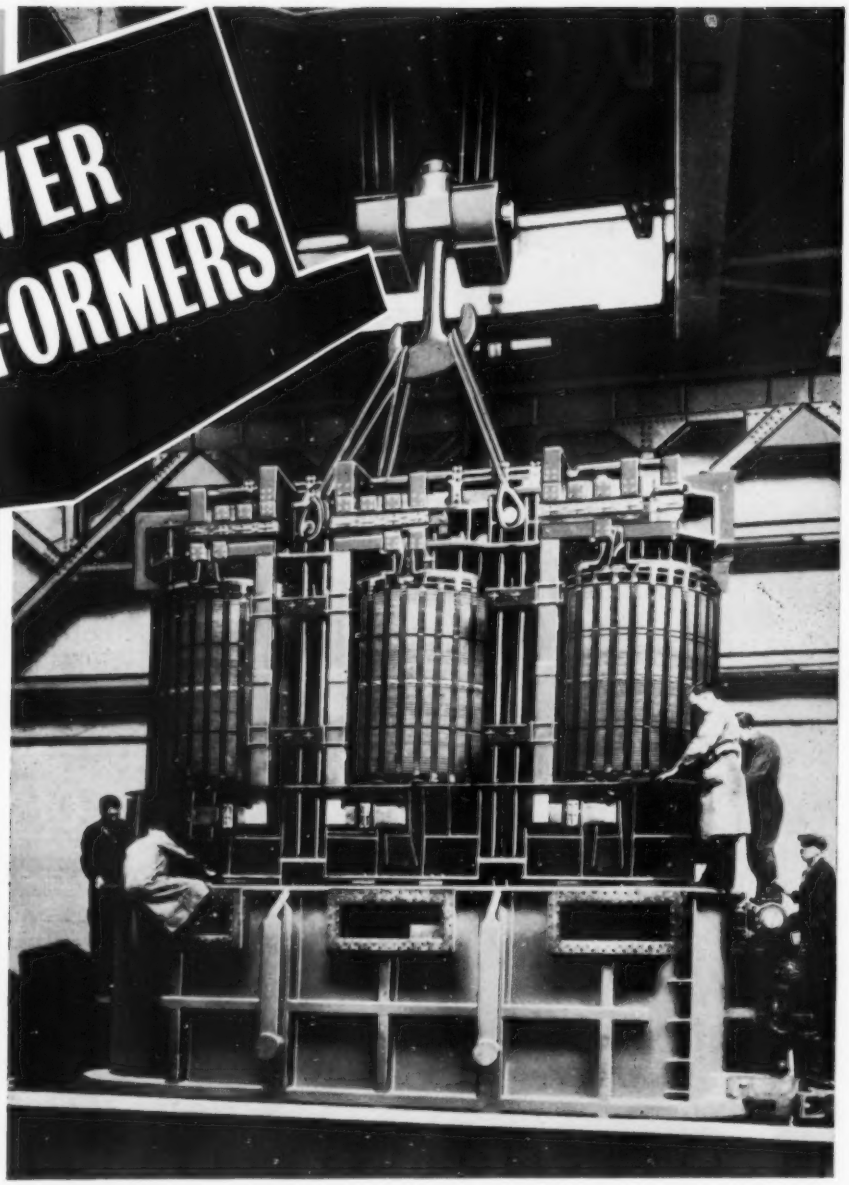
VIA LARGA 8 · MILANO · ITALY

Telephone: 898.142 *Cables: ELETTROBRENNERO, MILANO*

LONDON REPRESENTATIVE OFFICE: 2 VICTORIA STREET, S.W.1 *Telephone: ABBey 7210*

Subsidiary Companies, Branches and Representatives throughout the world

POWER TRANSFORMERS



The millions of kVA of Bruce Peebles Transformers in successful operation today constitute a reliable guide in selecting transformers to meet the demands of tomorrow.

Bruce Peebles manufacture power transformers in the largest sizes for service at all voltages. Typical units in course of manufacture are 120,000 kVA 275,000-volt auto-transformers for the British Super-Grid.

Illustration shows a 75,000 kVA generator transformer in course of erection. It is typical of numbers ordered for direct connection to the generator to operate as a combined unit.

BRUCE PEEBLES

& CO. LTD. · EDINBURGH · SCOTLAND

ACCESSORIES

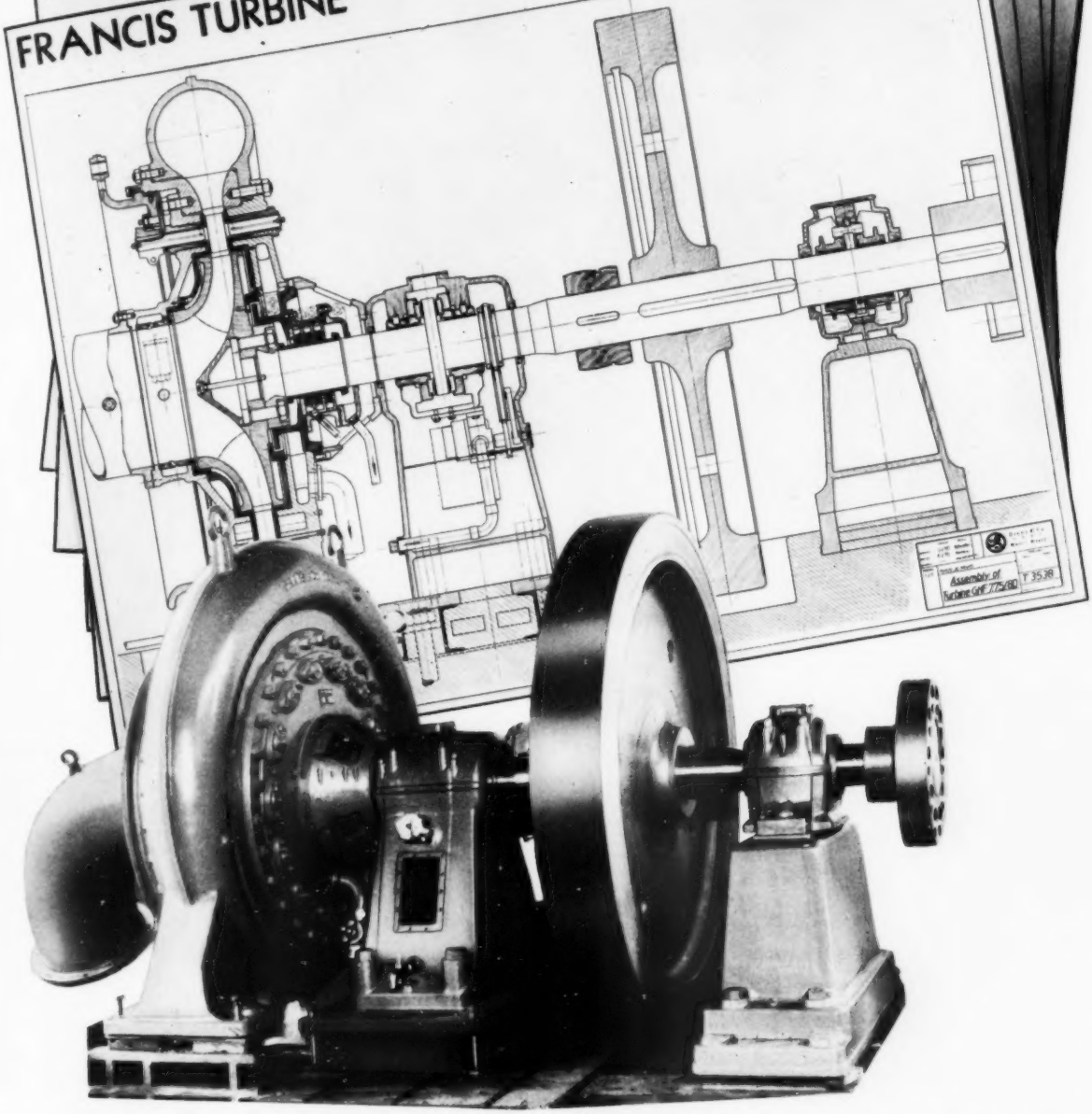
HYDRO-ELECTRIC UNIT

PELTON TURBINE

KAPLAN TURBINE

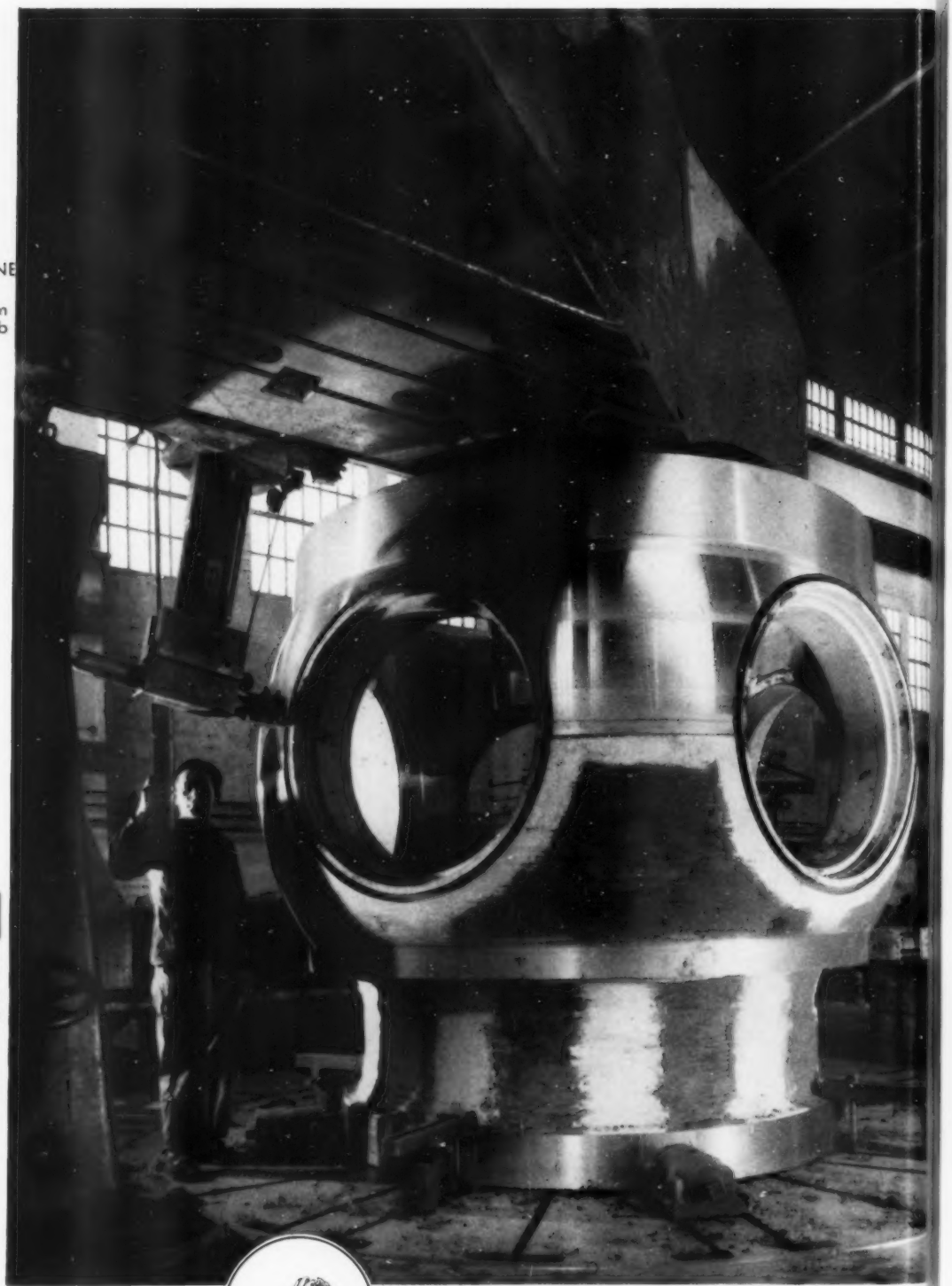
FRANCIS TURBINE

DREES



DREES & CO. G.M.B.H. WERL, GERMANY

OUR WATERTURBINES ARE RUNNING IN: TURKEY, THE LIBANON, PAKISTAN, IRAN, INDIA, THAILAND, THE PHILIPPINES, INDONESIA, NEW ZEALAND, S. A. U., BELG. CONGO, PORT. ANGOLA, MAURITIUS, MEXICO, COSTARICA, GUATEMALA, NICARAGUA, COLUMBIA, VENEZUELA, ECUADOR, PERU, BRAZIL, THE ARGENTINE, CHILE, GREECE, YUGOSLAVIA, ITALY, RUMANIA, BULGARIA, AUSTRIA, CZECHOSLOVAKIA, LUXEMBURG, HOLLAND, BELGIUM, DENMARK, ICELAND, SPAIN



HATEAUNEUF-du-RHONE
FRANCE
›2,450 H.P. Kaplan
urbines a runner hub
being machined

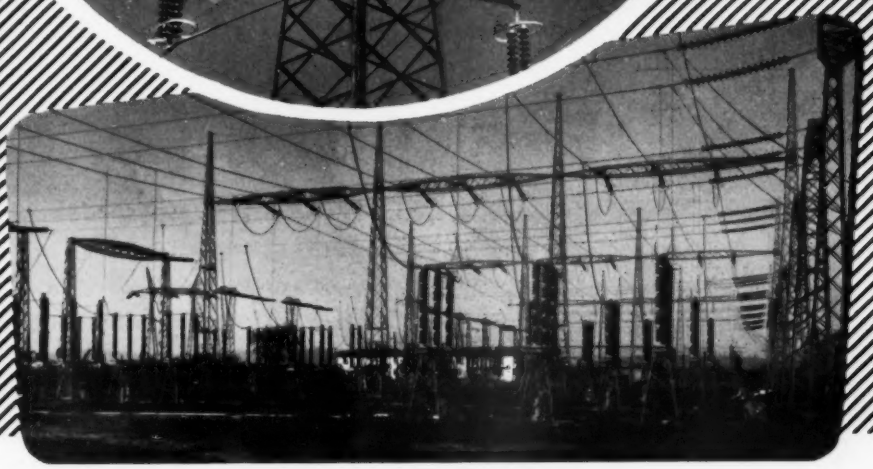
NEYRPIC

R E N O B L E
renue de Beauvert
P. 52 - Tel. 44-55.30
A R I S (V I I I)
5, Bd Haussmann
l. BALZAC 03-12

NEYRPIC

GRENOBLE-FRANCE

SALVI



3-220 kV Villa Valle-Cornegliano 4 Twin S.C.A. Conductor Transmission Line (Societa TERNI-Rome)

For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints.
The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV, and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES
(EXCEPT AUSTRALIA AND NEW ZEALAND) AND BRITISH COLONIES AND PROTECTORATES

THE ENGLISH SALVI COMPANY LTD., 11 Kensington Church St., London, W.8

Telephones: WEStern 8857 and 4412 Cables: ENSALVICO, LONDON

HITACHI

Power Plant and Substation Equipment

Hitachi's waterwheel driven alternators are backed with more than half a century of indefatigable research and engineering experience. Several thousands of HITACHI alternators in a wide variety of capacities have already been supplied with satisfactory results in power plants both at home and overseas.

Waterwheels	Power Transformers	Static Condensers
Alternators	D.C. Generators	Induction Regulators
Steam Turbines	Circuit Breakers	Disconnecting Switches
Boilers	Rotary Converters	Lightning Arresters
Frequency Changers	Mercury Rectifiers	Switchboards

Hitachi, Ltd.
Tokyo Japan

Cable Address : "HITACHY" TOKYO

The Painter's View

Desert Highway

THE sun-baked desert is a long way from our works at Hereford, but in far-away places, from Basra to Brazil, you will find Painter Brothers' towers standing untroubled either by extremes of temperature or of humidity, because we are specialists and understand these problems.

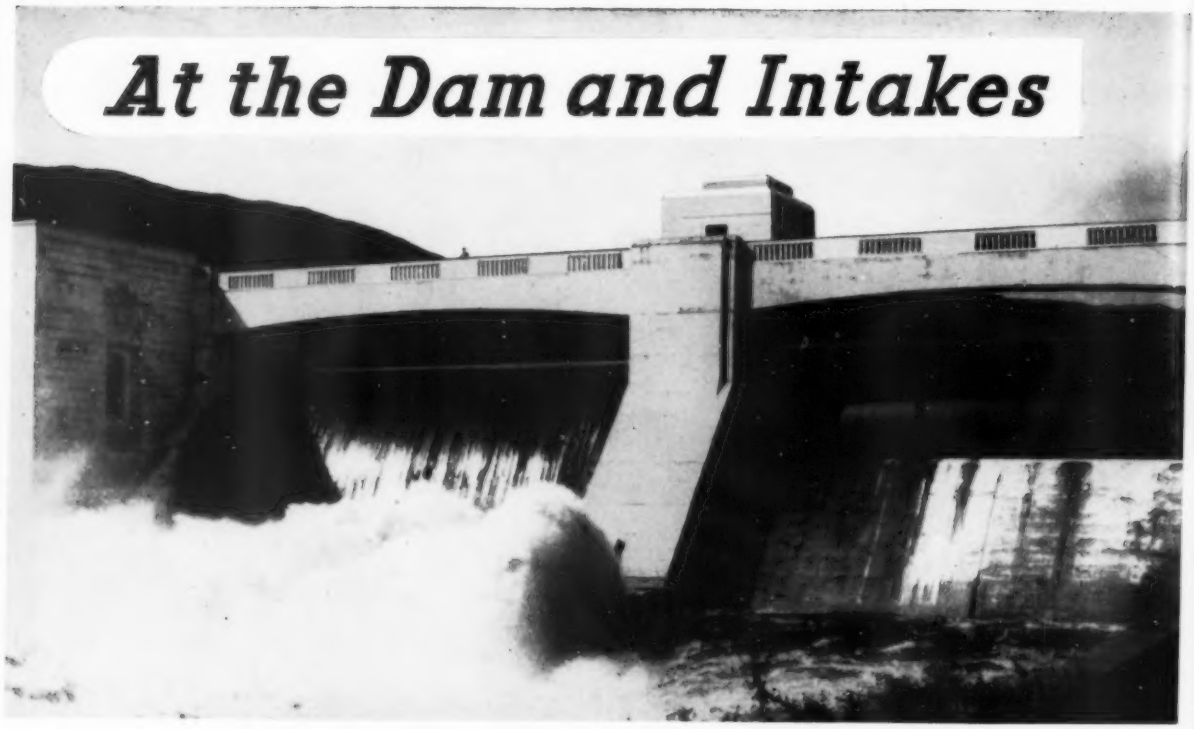
Because we have always been Tower Specialists and have developed our own fabrication methods which ensure accuracy and interchangeability; because we have had nearly thirty years' experience of hot dip galvanising, and because we have our own Tower Testing Station to prove the behaviour of structures under every sort of loading condition, Painter Brothers' towers are Towers of Strength.

Painter Bros. Ltd.

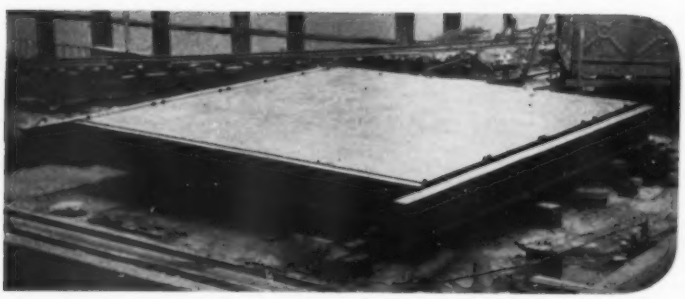
HEREFORD

Overhead Electrical Transmission Towers and Poles; Radio Masts; Callender-Hamilton Bridges.

At the Dam and Intakes



CONTROL GATES



for Spillway Crests, and Tunnel and Turbine Intakes have for long been a Glenfield speciality, and can be supplied in a variety of forms covering Direct Lift, Double Leaf, Drum, Radial and Tilting. The illustrations show 90 ft. span by 16 ft. deep automatic Drum Gates installed on Pitlochry Dam, Tummel-Garry Hydro-Electric Scheme, Scotland; and one of ten 21 ft. 3 in. span by 22 ft. 10½ in. deep Free Roller Direct Lift Gates supplied for the turbine intakes of the Owen Falls Scheme, Uganda.

Glenfield

GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

Head Office and Works
KILMARNOCK SCOTLAND

Valve Specialists and Hydraulic Engineers for over one hundred years

BULLERS LIMITED

London Office :
6 Laurence Pountney Hill, E.C.4
Phone : MANsion House 9971

MILTON · STOKE-ON-TRENT · STAFFS
Phone : Stoke-on-Trent 21381 (5 lines)
Telegrams & Cables : Bullers, Stoke-on-Trent

Iron Works :
Tipton · Staffordshire
Phone : Tipton 1691

POST INSULATORS

FOR 275 K.V. SWITCHGEAR

This post insulator was designed and manufactured by Bullers Limited to the requirements of the British Electricity Authorities specification for 275 K.V. Switchgear.

BULLERS LIMITED design and manufacture both porcelain and metal parts in their own works.

Enquiries are invited for porcelain insulators and fittings for any voltage and mechanical loading.

We specialise in :

Porcelain for general insulation.

Frequelex for high frequency insulation.

Permalex and Templex for capacitators refractories.

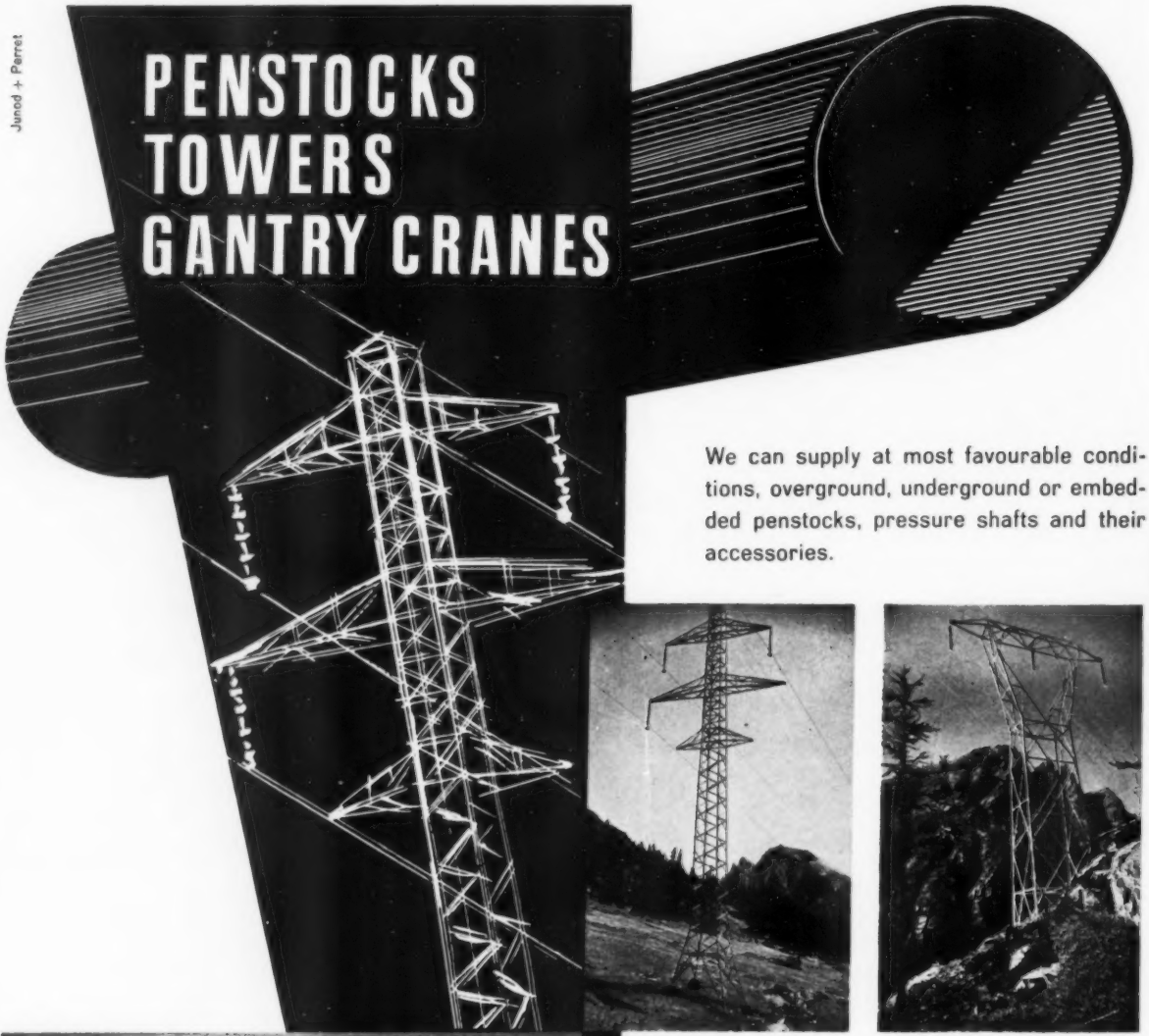
Fittings for insulators and overhead lines, etc.

Height of post 116"
Cantilever strength 2,000 lb.
Dry withstand test 580 K.V.
Wet withstand test 520 K.V.

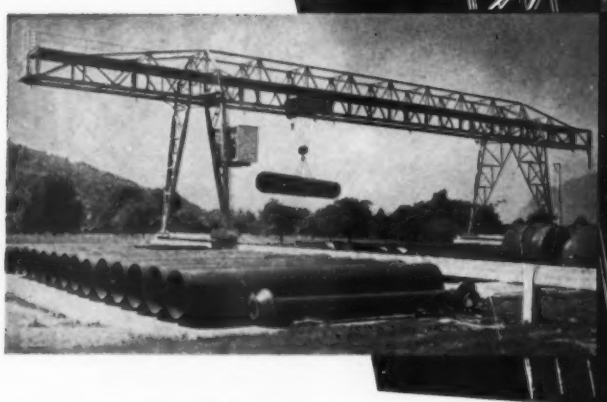
BLSA

Junod + Perret

PENSTOCKS
TOWERS
GANTRY CRANES



We can supply at most favourable conditions, overground, underground or embedded penstocks, pressure shafts and their accessories.



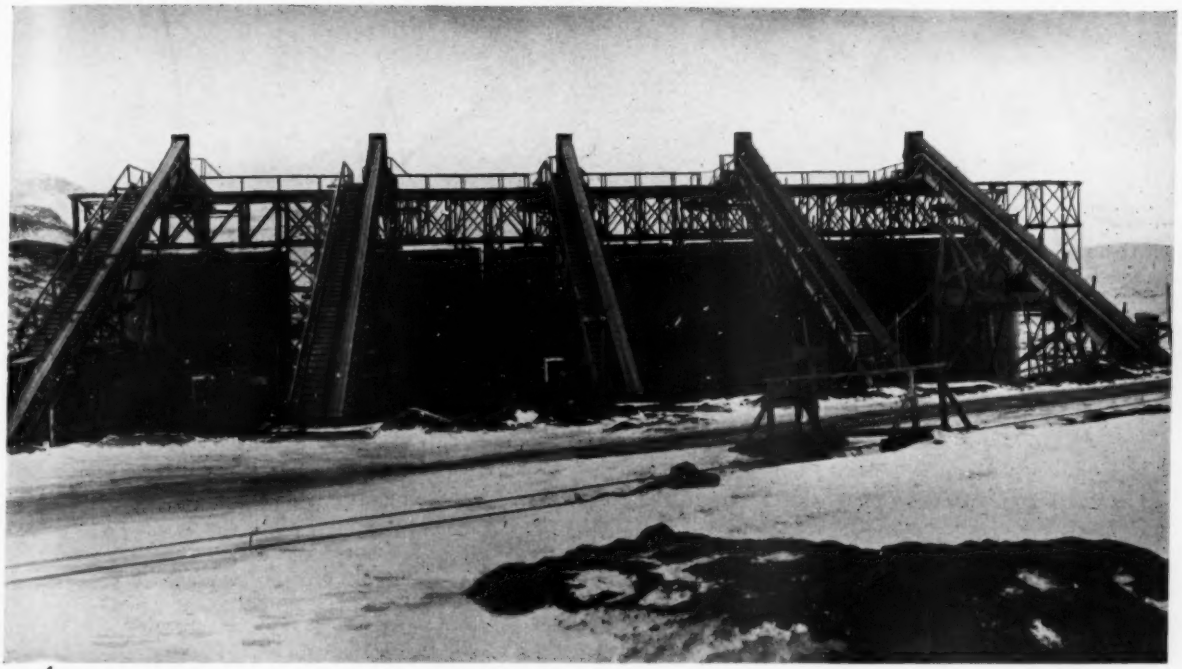
Towers for electric transmission lines, for teleferics or radio aerials.
Steel structures for buildings.
Reservoirs of any shape and dimensions.

Gantry crane, lifting capacity 3 to 25 tons, distance between rails 36 m., 2 overhangs of 12 m., total length 60 m.

giovanola

GIOVANOLA FRÈRES S. A., MONTHEY (VS) SUISSE

Building for Power →



with HUWOOD conveyors.

Huwood Conveyors are in wide use, not only in Britain but throughout the world—one of their most important applications being in the work of dam building for hydro-electric schemes.
They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

Some hydro-electric schemes at which Huwood Conveyors have been, or are being used—

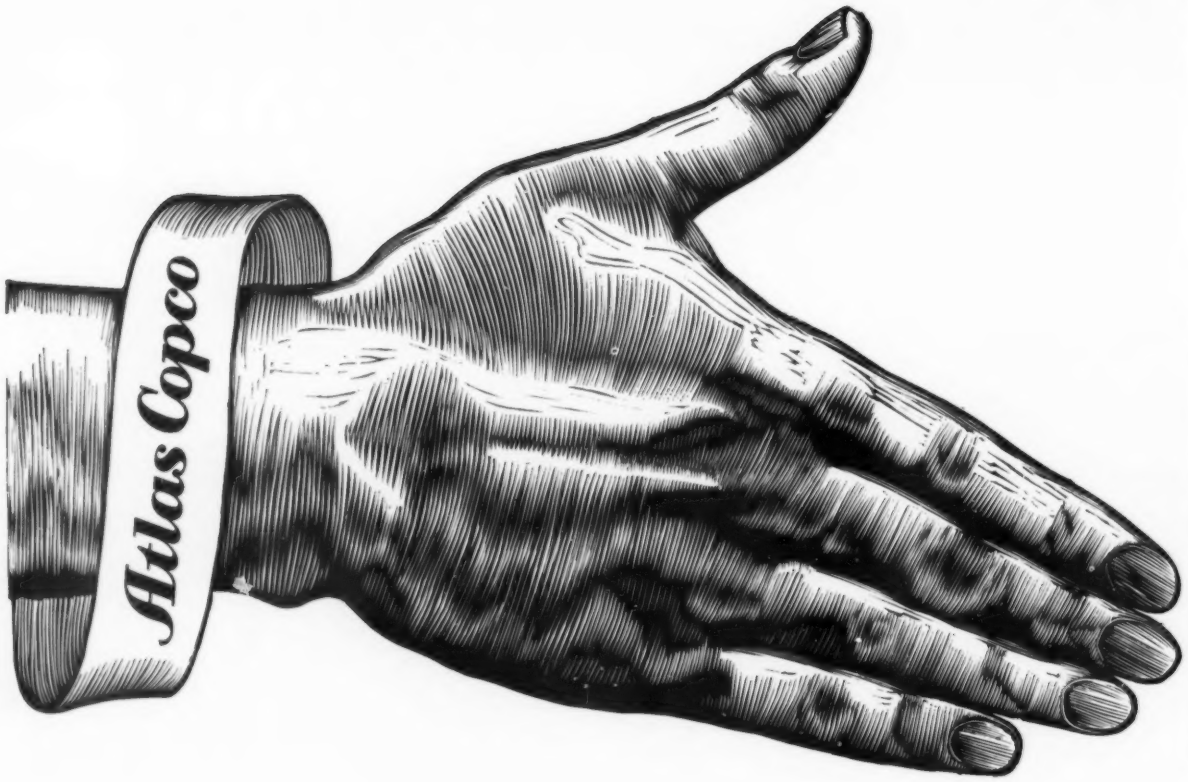
SCOTLAND.	Tummel Garry - Loch Sloy - Errochty Dam Lawers Dam
AFRICA.	Owen Falls - Uganda
INDIA.	Hirakud Dam Project

HUGH WOOD & CO. LTD.

Head Office and Factories - GATESHEAD-ON-TYNE, 11

Industrial and Export Office

HUGH WOOD & CO. LTD., DASHWOOD HOUSE, 69 OLD BROAD ST., LONDON, E.C.2



A great new partnership! Arpic Engineering—one of the foremost manufacturers of portable compressors—is now a part of the Atlas Copco Group of Companies. This will result in the

mutual pooling of production resources and technical ideas, and in the increase of existing world servicing facilities. Read on, about the advantages this will bring you. . . .

Turn to next page

Now that Arpic are part of the Atlas Copco Group you will be able to choose a compressor from one of the biggest ranges of portables in the world

Atlas Copco manufacture a wide range of portable compressors, but not a complete range. This also applies to Arpic. However, the new *combined* range of portables is one of the most comprehensive in the world. From one source you can now choose portable compressors with air deliveries ranging from 36 to 550 cubic feet per minute. From the smallest to the largest, and all sizes in between. Portables for any operation, any climate and any altitude.

INCREASED PRODUCTION FACILITIES WILL SPEED DELIVERY

Now that Atlas Copco and Arpic are one, their various plants will be at the disposal of a common direction and a combined team of production engineers. This dovetailing of facilities will mean increased production, as well as earlier, more reliable delivery dates for all types of compressors. It will also speed maintenance work and the supply of spare parts.

The compressors formerly sold under the Arpic name will henceforth be known as Atlas Copco Compressors, *Type Arpic*. They will continue to be manufactured and assembled at the plant in Antwerp, one of the biggest and most modern of its type in the world, and at an up-to-date plant in Glasgow.

POOLING OF TECHNICAL IDEAS WILL IMPROVE THE DESIGN OF COMPRESSORS

Both companies gain much by the pooling of technical information. You can expect, in the future, positive improvements in the design of all types of portable compressors. Atlas Copco and Arpic will now have access to the many outstanding technical features both companies have developed over the years. The new range of portable compressors will be more than comprehensive. It promises to be the most advanced and most reliable in the world.

AN EXTENDED WORLD-WIDE SERVICE

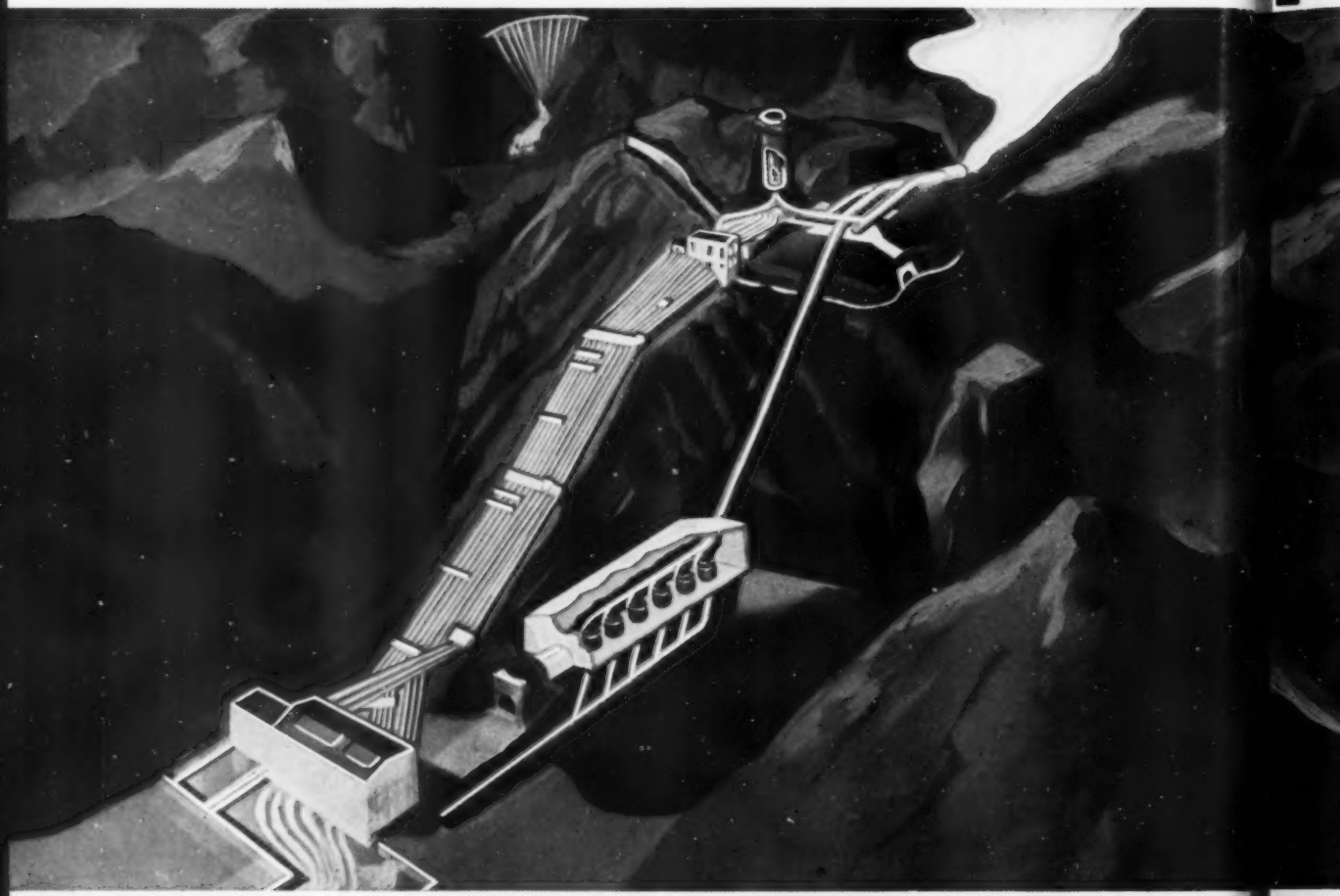
Arpic bring to Atlas Copco the services of something like 30 overseas depots. There will now be a total of 80 Atlas Copco companies or agents selling and servicing the new range of compressors all over the world. This reorientation greatly extends the on-the-spot service available to users.

The Atlas Copco Group of Companies

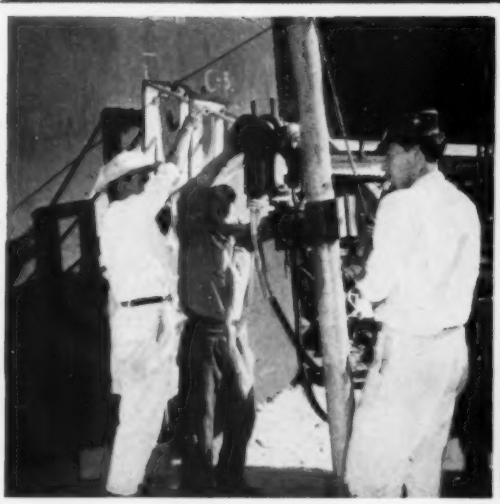
Compressed Air Engineers ★ Now incorporating the* ARPIC *Companies

For further details about the new range of compressors and the increased servicing facilities, write to your local Atlas Copco company or agent or to Atlas Copco AB, Stockholm 1, Sweden.

Here's why A.O.Smith **MULTI-LAYE**



WELDING — Latest techniques are used for automatic and manual welding of penstock sections. A team of A. O. Smith specialists is available for complete inspection and supervision of welding on the job, anywhere in the world.



X-RAY INSPECTION — All welds are x-ray inspected for weak spots. In three miles of weld in the above installation, less than two percent required repair. Magnetic particle inspection also used. Here, too, A. O. Smith fieldmen can give on-the-job supervision.

MULTI-LAYER CONSTRUCTION Walls are built-up from concentric lay thin plate steel . . . progressively wra tightened and welded around the inne to form a lighter but stronger penstock.

penstocks save money on high-head jobs

Save up to 15% in weight of steel required for conventional single-wall penstocks... lower shipping and installation cost ...eliminate costly stress-relieving of welds

ABOVE ground or under . . . A. O. Smith penstocks are the real answer to a lower cost high-head power plant.

Illustrated here are two power plants with A. O. Smith penstocks. More than 1300 ft. of penstock installed underground where the rock carries a portion of the load, and, *Multi-layer* penstocks, above-ground, provide water power for the famous Nilo Peçanha hydro-electric project of the Rio de Janeiro Tramway, Light & Power Co., Ltd.

As the name implies, *Multi-layer* construction consists of layers of thin plate steel of high tensile strength. Each layer is progressive wrapped around an inner core tightened a welded to form a lighter but stronger penstoc

This exclusive A. O. Smith design assures e tra-strength . . . saves up to 15% in weight steel as compared to conventional single-w penstocks of same diameter. What's more, t safety factor is the same despite considera reduction in weight. In addition, shipping a installation costs are less . . . costly stress-reli ing of welds is eliminated. And, with *Multi-la* design, there's no practical limitation to the pr sures that can be handled.

If you want to save material, freight and ca costs, erection and welding time, investig *Multi-layer* penstock design. Take advantage our unlimited research and production facili for penstock construction. For more informat on PENSTOCK design, write A. O. Smith C poration, International Division, P.O. Box 20 Milwaukee 1, Wisconsin, U.S.A.

MASSIVE WYES — At A. O. Smith, quality control never leaves the production floor. This giant "wye", for example, was hydrostatically tested at 1425 psi. Design is accurately verified by means of strain gauge and extensometer measurements.

Through research A.O. Smith *...a better*

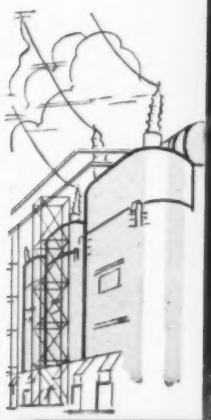
A.O.Smith

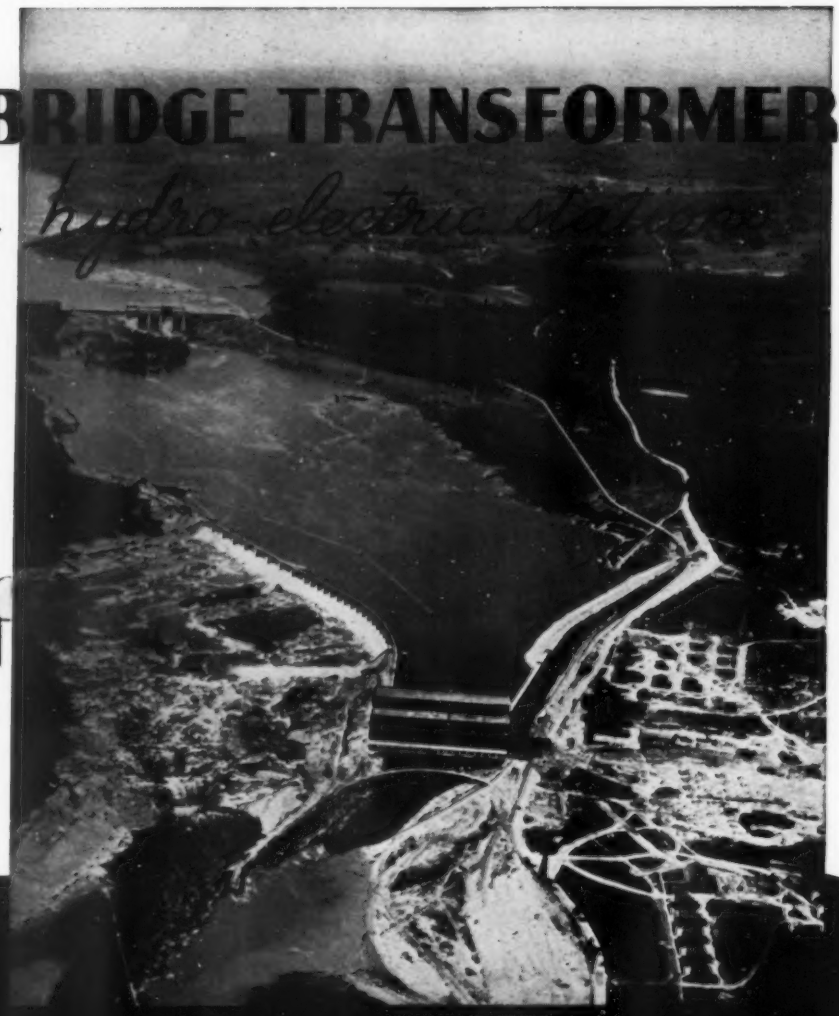
CORPORATION

INTERNATIONAL DIVISION
P. O. Box 2023
Milwaukee 1, Wisconsin, U.S.A.

HACKBRIDGE TRANSFORMERS

for hydro-electric stations





THE Hackbridge and Hewittic Electric Co. Ltd. has a long and extensive experience in the manufacture of water cooled and other types of Transformers, up to the largest sizes, for hydro-electric power distribution.

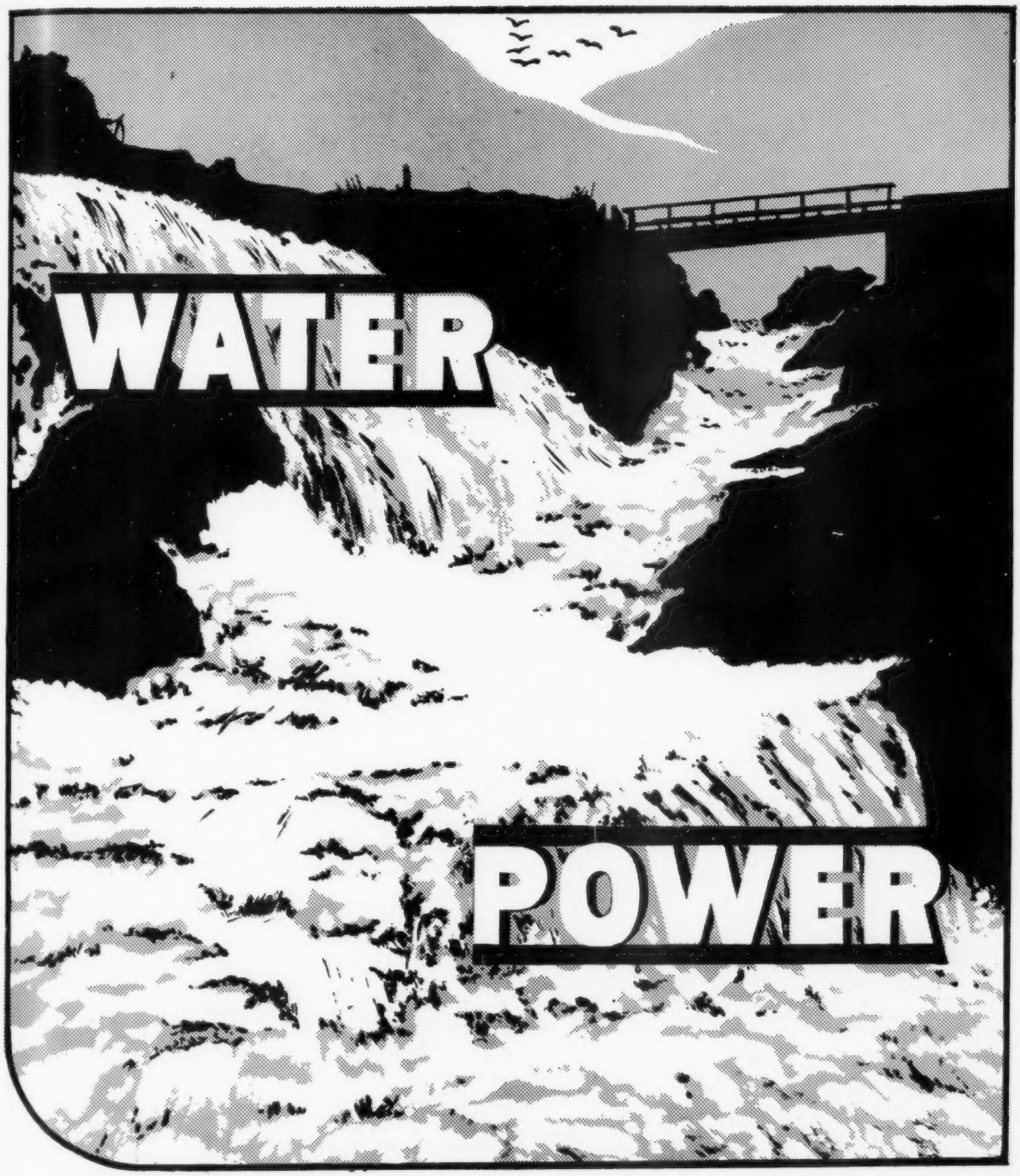
HACKBRIDGE Transformers have established an unrivalled reputation for *reliable service* in world-wide hydro-electric installations, with operating conditions ranging from the tropical heat of East Africa to the extreme cold of Northern Canada.

HACKBRIDGE AND HEWITTIC ELECTRIC CO., LIMITED
WALTON-ON-THAMES - SURREY - ENGLAND

Telephone: Walton-on-Thames 760 (8 lines) *Telegrams: "Electric, Walton-on-Thames"*

17.

OVERSEAS REPRESENTATIVES.—ARGENTINA: H. A. Roberts & Cia., S.R.L., Buenos Aires. AUSTRALIA: Hackbridge and Hewittic Electric Co. Ltd., 171 Fitzroy Street, St. Kilda, Victoria: N.S.W.: Queensland: W. Australia: Elder Smith & Co Ltd.: S. Australia: Parsons & Robertson Ltd. BELGIUM & LUXEMBOURG: M. Dorfman, 5 Avenue des Phalenes, Brussels. BRAZIL: Oscar G. Mors, Sao Paulo. CANADA: Hackbridge and Hewittic Electric Co. of Canada Ltd., Montreal: The Northern Electric Co. Ltd., Montreal, etc. CEYLON: Envee Ess Ltd. Colombo. CHILE: Ingenieria Electrica S.A.C., Santiago. EAST AFRICA: Gerald Hoe (Lighting) Ltd., Nairobi. EGYPT: Giacomo Cohenca Fils, S.A.E., Cairo. FINLAND: Sähkö-ja Koneliike O.Y. Hermes, Helsinki. HOLLAND: J. Kater E.I., Ouderkerk a.d Amstel, Amsteldijk Noord, 103c. INDIA: Steam & Mining Equipment (India) Ltd., Calcutta; Easun Engineering Co. Ltd, Madras, I. IRAQ: J. P. Bahoshy Bros. Baghdad. MALAYA, SINGAPORE & BORNEO: Harper, Gilfillan & Co. Ltd., Kuala Lumpur. NEW ZEALAND: Richardson, McCabe & Co. Ltd., Wellington, etc. PAKISTAN: James Finlay & Co. Ltd., Karachi. SOUTH AFRICA: Fraser & Chalmers (S.A.) (Pty.) Ltd., Johannesburg. CENTRAL AFRICAN FEDERATION: Fraser & Chalmers (S.A.) (Pty.) Ltd., Salisbury, etc. THAILAND: Vichien Phanich Co. Ltd., Bangkok. TRINIDAD & TOBAGO: Thomas Peake & Co., Port of Spain. TURKEY: Dr. H. Salim Öker, Ankara. URUGUAY: H. A. Roberts & Cia., S.A.U., Montevideo. U.S.A.: Hackbridge & Hewittic Electric Co. Ltd., P.O. Box 234, Pittsburgh 30, Pennsylvania.



PIPELINES FOR HYDRO-ELECTRIC PLANTS

Design · Supply · Erection

DIR. THV. HEYERDAHL, FERRUM MONTAGE A/S **OSLO**

TELEPHONE : 464903 *CABLES : FERRUMPIPE, OSLO*

FERRUM (ENGLAND) LTD., 43 NORFOLK STREET, LONDON, W.C.2

TELEPHONE : TEMPLE BAR 2528 *TELEGRAMS : FERRUMPIPE, LONDON*

Highland water power

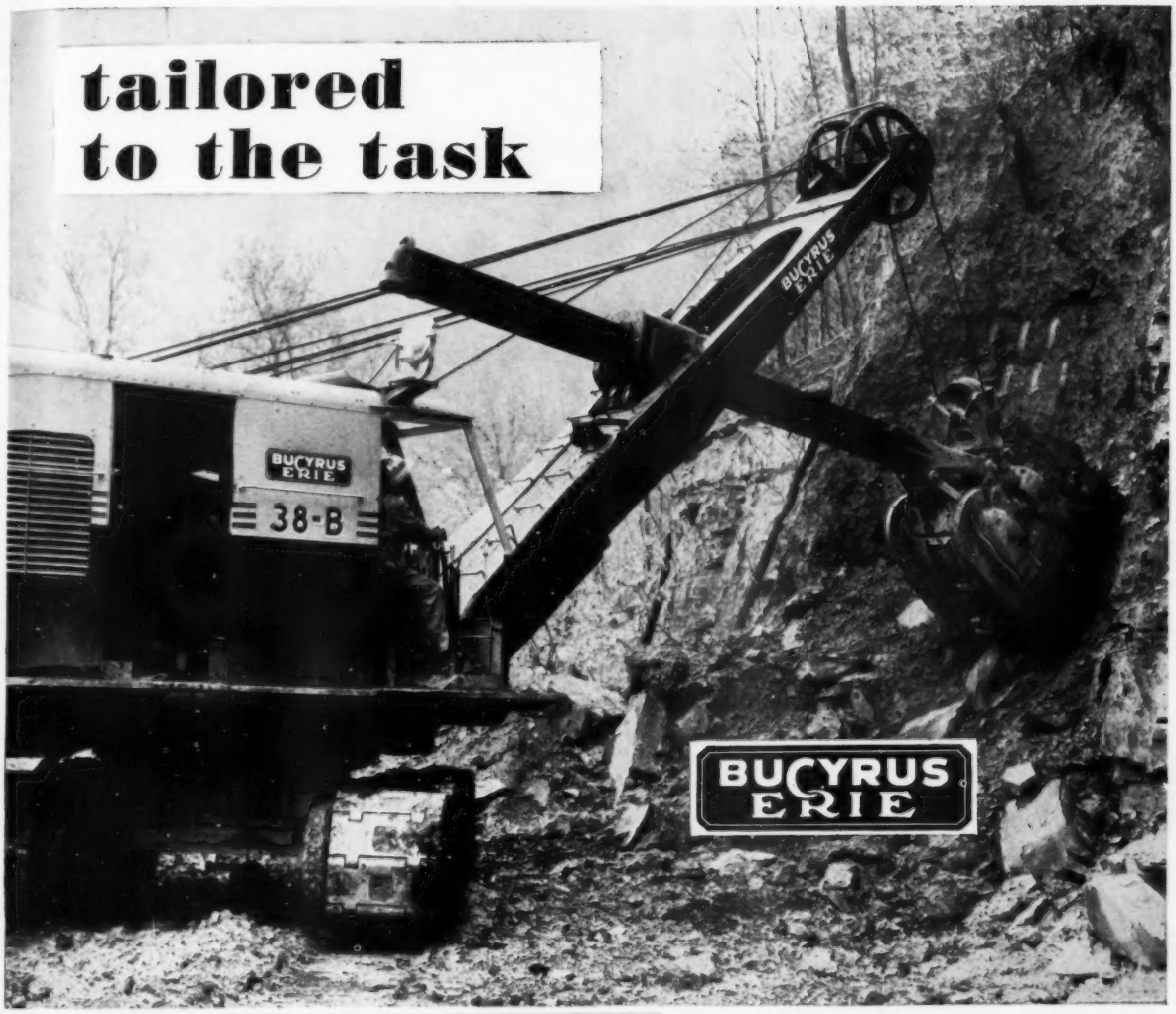
This is Errochty power station on the shore of Loch Tummel. It is the largest generating station in the Tummel-Gary Scheme of the North of Scotland Hydro-Electric Board, and houses three 25 MW vertical-shaft hydro-alternators built and installed by G.E.C. Auxiliary motors and most of the control gear in the station were also supplied by G.E.C.

G.E.C.

HYDRO-ELECTRIC PLANT

THE GENERAL ELECTRIC CO. LTD · MAGNET HOUSE · KINGSWAY · LONDON · W.C.2

tailored to the task



Each size of Bucyrus-Erie excavator is individually designed all the way through from caterpillar tracks to boom-point sheaves for a definite size payload. For example, in every detail of this power-packed 38-B 1½ cubic yard shovel the strength is there to meet demands. Furthermore, with main machinery, power unit and mounting all perfectly matched to front-end capacity, the danger of over-stressing gears, shafts, drums, clutches, ropes, etc., is reduced to a minimum.

As shovel, dragline or dragshovel you can depend on a 38-B for hard work.

BUCYRUS—ERIE

BUCYRUS-ERIE CO · SOUTH MILWAUKEE · WISCONSIN · U.S.A. ★ RUSTON-BUCYRUS LTD · LINCOLN · ENGLAND

2570

Sécheron

Generators and motors with capacities above 150 kW / Single-phase and three-phase transformers for all outputs and voltages / Electrical applications in the field of traction / Installations of pumpless mercury arc rectifiers with rare gas filling / High-speed automatic regulators applied to various control problems / Welding rods and electric arc welding sets.

Sécheron production is renowned for quality.

S.A. DES ATELIERS DE SÉCHERON / GENEVA

Installation of these two 5'-high SMS Bascule Gates on a dam 28' in height will enable the City of Decatur, Illinois, to more than double its present water storage capacity, even in dry years. The training wall and concrete pier between the gates is designed to minimize downstream cross-flow and damage to the apron. Harza Engineering Co., Chicago, Illinois, Consulting Engineers.

Individual 29'-long sections of the gate are installed in graphited bronze bearing shoes. A Bascule Gate was chosen over other types here when engineering studies proved it most economical and simplest.

View from downstream side shows final connection of one of the several hydraulic operating cylinders for each gate. Piping on the face of the dam immediately below provides individual isolation of any cylinder.

One of the two 500 psi oil accumulator tanks is about to be raised into position at the control station. Pumps supply pressure to the accumulator tanks for emergency operation in the event of power failure.

New SMS Bascule Gate Design Provides a CLEAR CREST, UNLIMITED LENGTH

Now SMS Bascule Gates can be built to any length you need, and installed without intermediate piers or overhead structures. With this new SMS design, hydraulic operators are located under the gate leaves and controlled from either end. The installation shown above consists of two 233'9" gates. They are the longest ever installed.

An SMS Bascule Gate will increase the storage and spillway capacity of existing dams quickly and economically. It enables you to control heavy run-offs without losing stored water, and to handle regional hazards like ice and heavy debris. In its open position, the gate lies flat on the dam crest and presents no obstruction to flow.

For full information on this new SMS Bascule Gate design—or on hydraulic turbines and other accessories—write to S. Morgan Smith Co., York, Penna.

S. MORGAN SMITH

AFFILIATE: S. MORGAN SMITH, CANADA, LIMITED, TORONTO

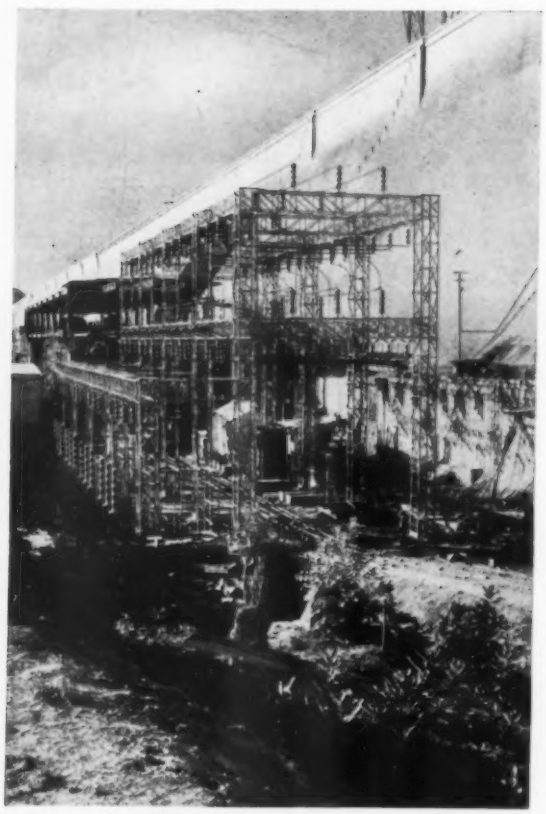
Licensees: The Harland Engineering Company, Ltd., Alloa, Scotland
Tokyo Shibaura Electric Co., Ltd., Japan

HYDRAULIC TURBINES
PUMPS
GATES & HOISTS
TRASH RAKES
LIQUID HEATERS

HYDRODYNAMICS

ROTOVALVES
BALL VALVES
BUTTERFLY VALVES
FREE DISCHARGE VALVES
CONTROLLABLE-PITCH SHIP PROPELLERS

The Mettur Dam sub-station is one of many in South India equipped with posts type P.642 for 66KV and 110KV.



Photograph reproduced by courtesy of the main contractors, Messrs. A.E.I. (India) Ltd.

S.P.P. POST INSULATORS were used for the METTUR DAM SUB-STATION MADRAS

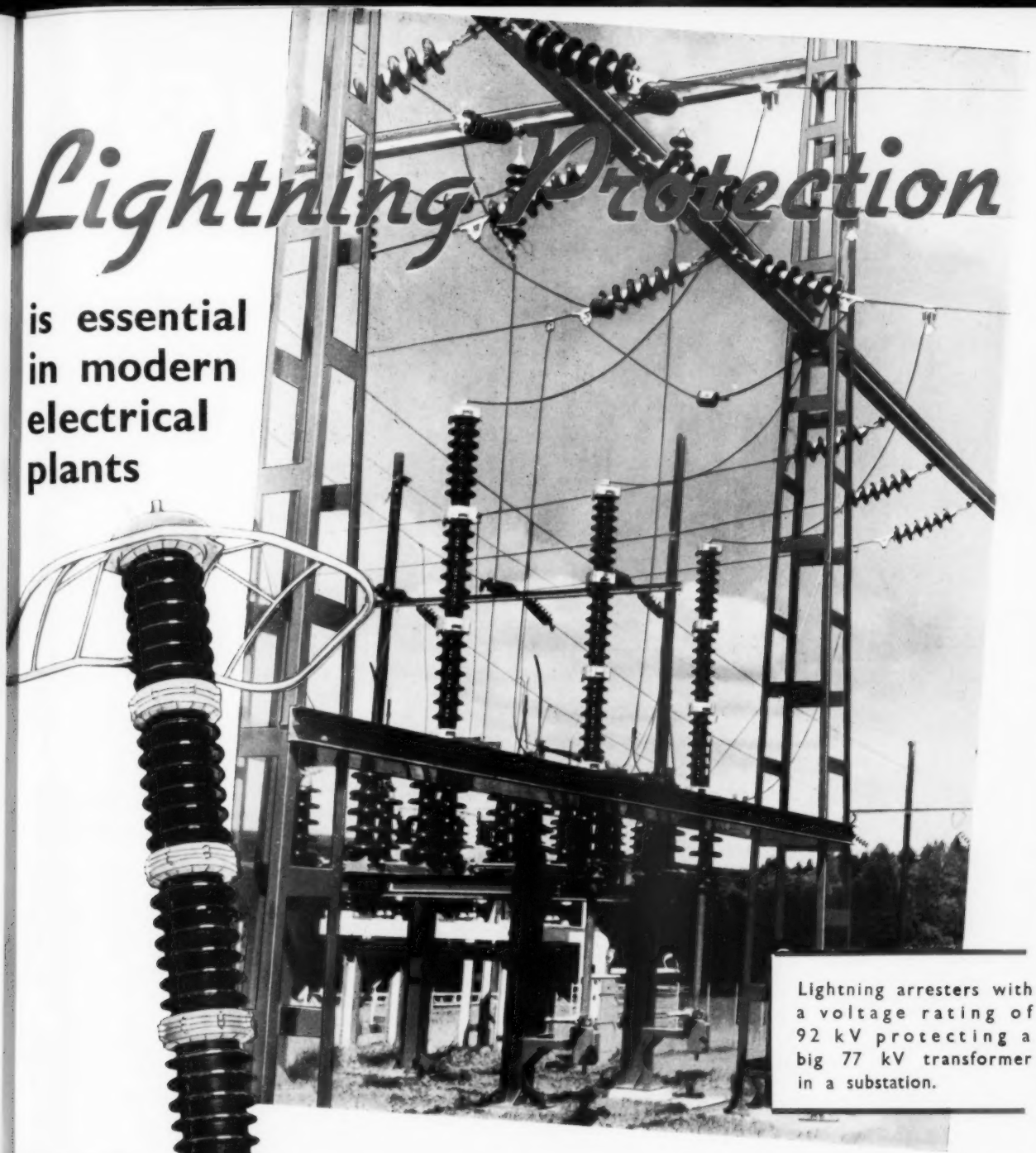
STEATITE & PORCELAIN PRODUCTS LTD.

Stourport-on-Severn, Worcestershire Telephone: Stourport 111 Telegrams: Steatain, Stourport

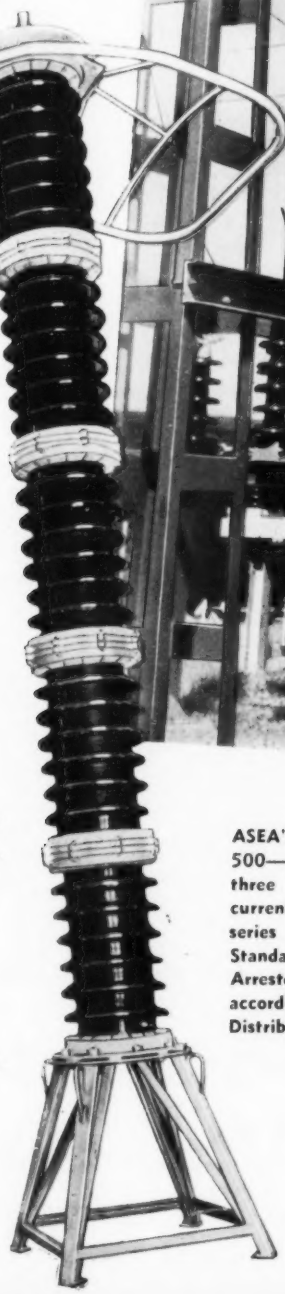
S.P.36

Lightning Protection

is essential in modern electrical plants



Lightning arresters with a voltage rating of 92 kV protecting a big 77 kV transformer in a substation.



Lightning arrester with a voltage rating of 400 kV. This type is installed in all stations in the Swedish 380 kV network.

ASEA's lightning arresters cover the range 500—400,000 V and are manufactured in three different series according to their current rating: a heavy duty and a standard series tested according to the American Standards AIEE 28 A 1950 for Station Arresters (10,000 A) and a light series tested according to the same Standards for Line and Distribution Arresters (5,000 A)

Outstanding features :

Low spark-over level at high impulse steepness. Low discharge voltage. Precision in manufacture : discharge voltage guaranteed to ± 5 per cent. Perfect sealing. Built as a self-supporting column up to the highest ratings, with consequent low installation costs.

It is cheaper in the long run to install ASEA's efficient lightning arresters and avoid expensive repairs and service interruptions due to damaged equipment and blown high voltage fuses.

For all your lightning protection problems — consult

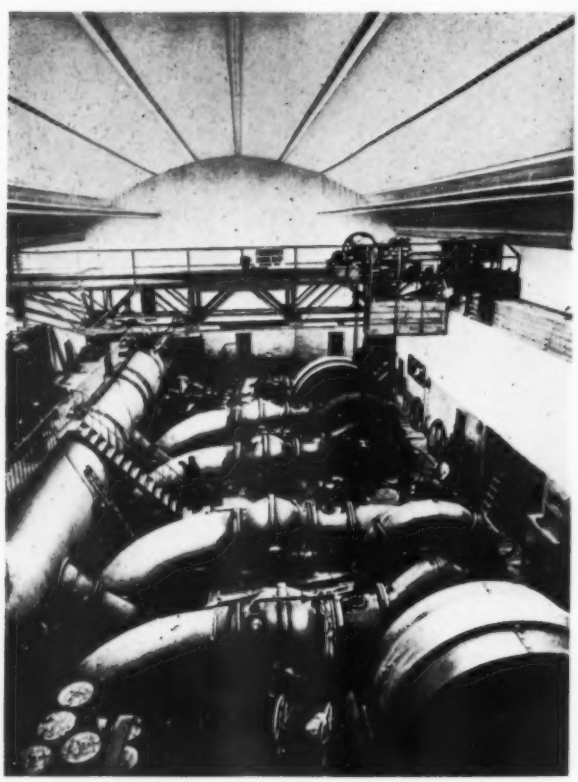
Västerås **ASEA** Sweden

MADE IN AUSTRIA

this is . . .

Austria's most beautiful wrought-iron well. During past centuries in the town of Bruck, Styria, drinking water was drawn out of this well in buckets.

Photo:
Österr. Nationalbibliothek



. . . and that is

the biggest and highest situated pumping plant in Austria. Mighty pumps, driven by two ELIN three-phase squirrel-cage motors for direct starting, 9,100 H.P. at 495 r.p.m. each, carry millions of cubic feet of glacier water to the Mooserboden storage reservoir at Kaprun power plant.

Photo: TKW

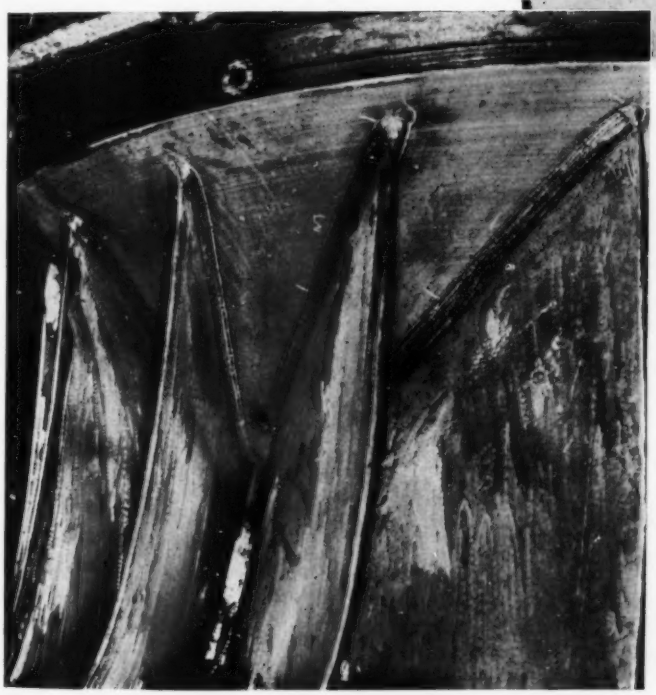
"ELIN"
VIENNA AUSTRIA

AKTIENGESELLSCHAFT FÜR ELEKTRISCHE INDUSTRIE

Modern construction of Francis runners

The runner shown on these pictures is of *welded* construction with blades and rim of stainless steel (Chromium 13%) and hub of plain carbon steel. The welding is effected according to a new, simple method using electrical induction for the necessary pre-heating. On this runner the welding results have been most successful.

Welded joints before final grinding.



Our normal design of *welded* Francis runners

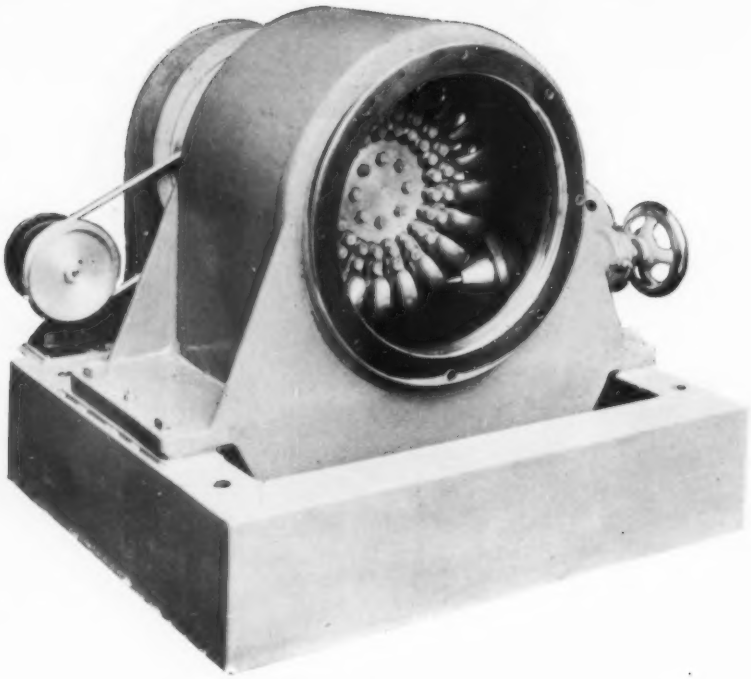
KMW also manufacture Francis runners of welded construction according to their patented method. In this case the runners are made of plain carbon steel with only those parts which may be exposed to cavitation damage coated with corrosion resistant material. The coating is effected in a simple and reliable way before welding the various parts together. By this means the manufacturing costs are appreciably reduced.

Further advantages with *welded* construction: Great accuracy in manufacture. All surfaces in the waterways completely finished before assembly of the runner.

Up to now we have manufactured about 35 runners of diameters up to 16 feet and for heads up to 305 feet using this method.

AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD

Karlstad • Sweden



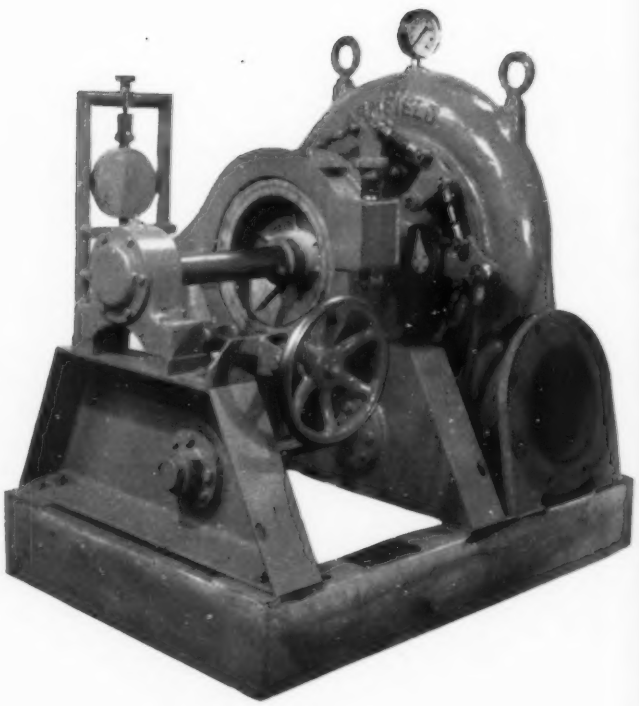
Left: No. O Pelton Turbine

Below: Francis Turbine with Prony Brake

LABORATORY WATER TURBINES

Our company has specialised for many years in modern scale models of hydraulic turbines to assist universities and technical colleges to prepare their students for the ever increasing field of Water Power Engineering.

Pelton Turbines — Francis Turbines — Turbines with Interchangeable Francis and Kaplan wheels — Special machines for post graduate research work.



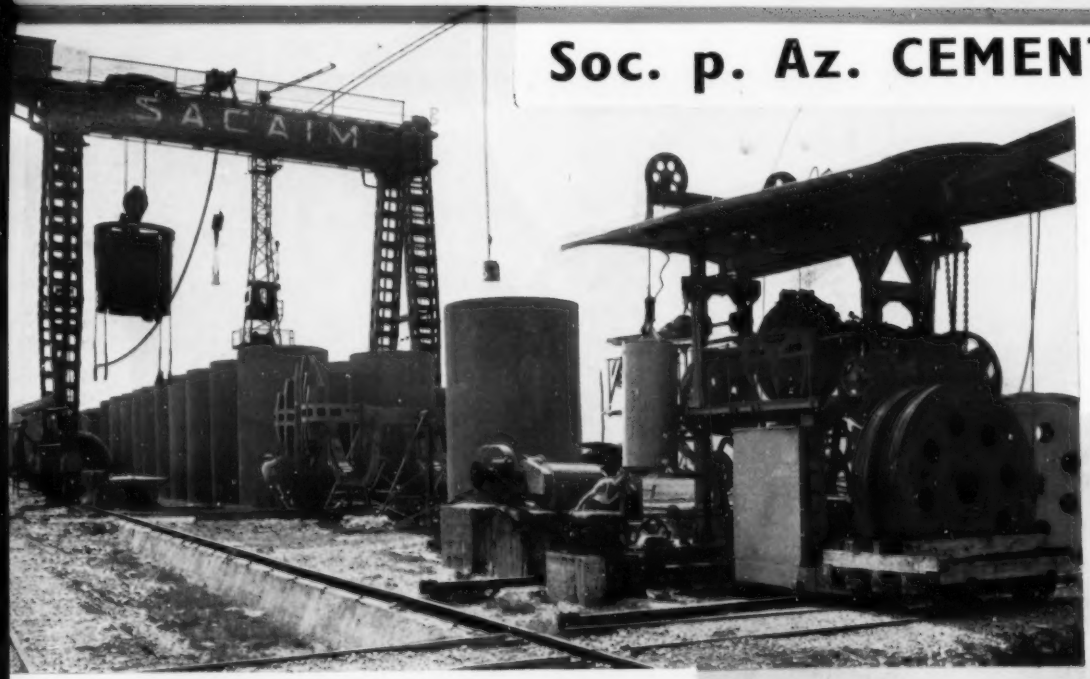
THE

ARMFIELD

HYDRAULIC ENGINEERING CO. LTD.,
RINGWOOD.

SK 281

Soc. p. Az. CEMENTI ARMATI Ing. MANTELLI



Soc. p. Az. CEMENTI ARMATI Ing. MANTELLI

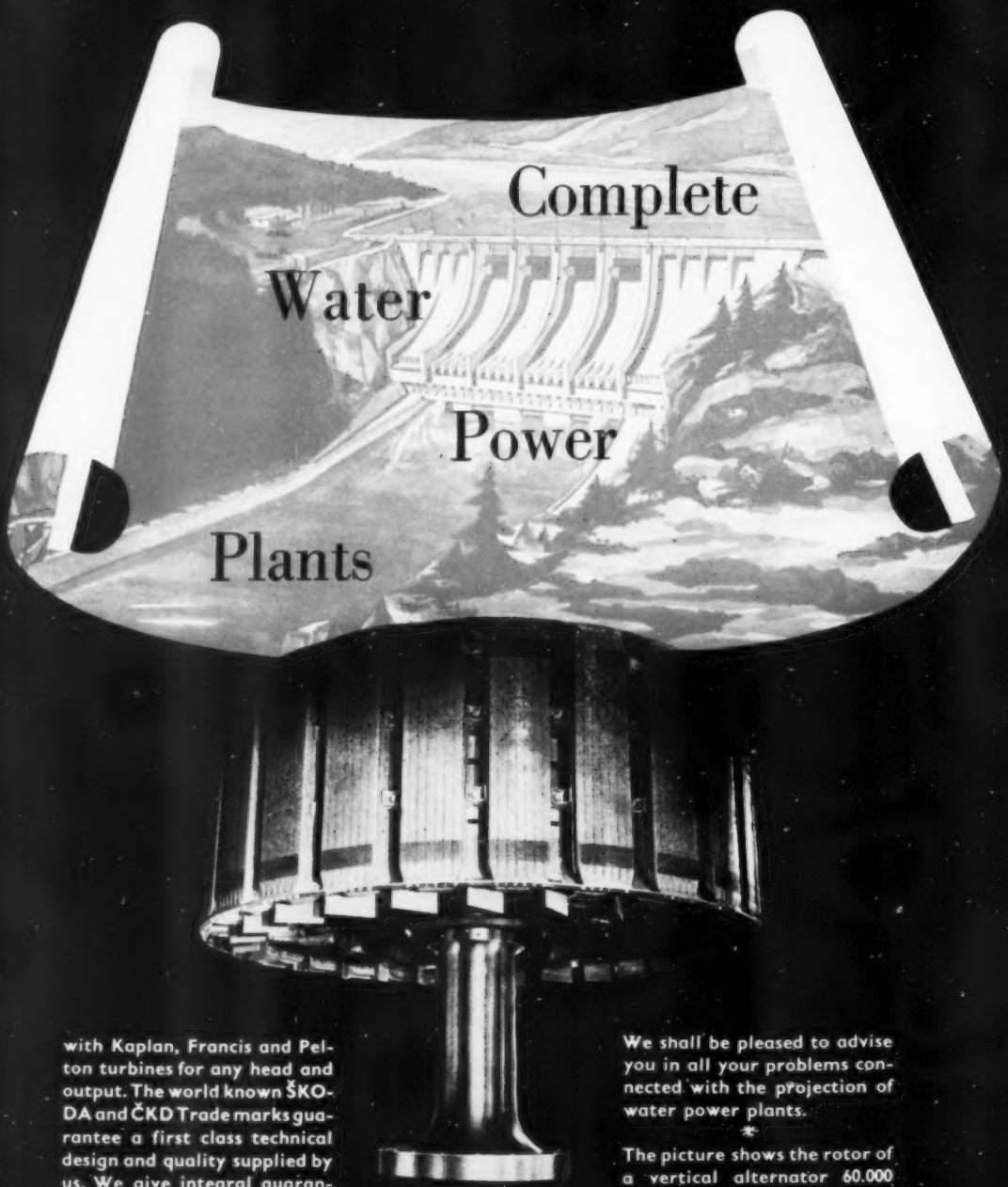
VENEZIA - Accademia No. 979a · Tel. 24-072

SACAIM

Prestressed reinforced concrete Penstocks (internal diameter 2.60 metres) for the Meduna hydro-electric station of

S.A.I.C.I.

SOC. AGRICOLA INDUSTRIALE PER LA CELLULOSA ITALIANA di MILANO



with Kaplan, Francis and Pelton turbines for any head and output. The world known ŠKODA and ČKD Trade marks guarantee a first class technical design and quality supplied by us. We give integral guarantees for complete deliveries.

We shall be pleased to advise you in all your problems connected with the projection of water power plants.

*

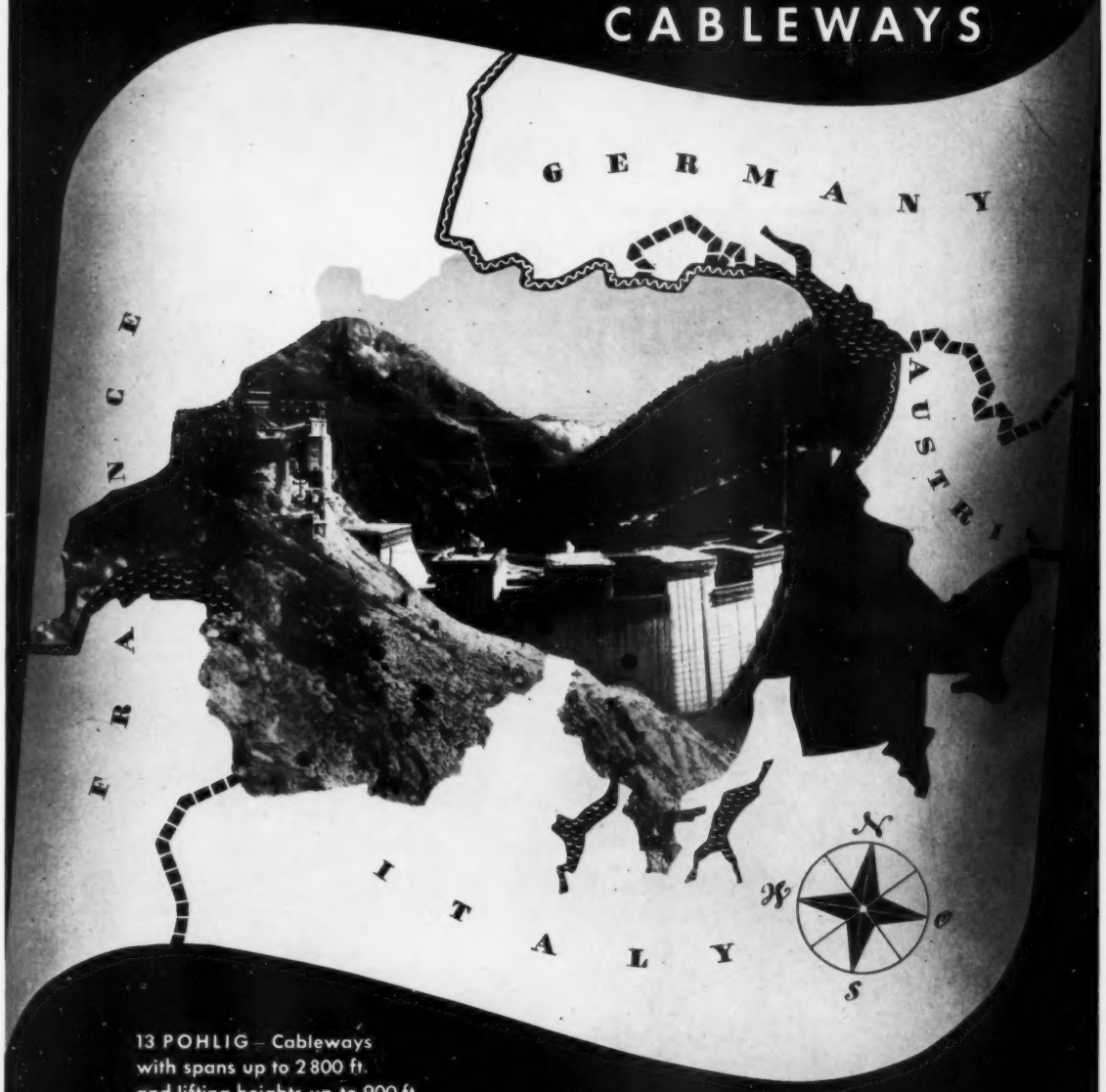
The picture shows the rotor of a vertical alternator 60.000 kVA, 10,5 kV, 230.8 r. p. m.

TECHNOEXPORT

FOREIGN TRADE CORPORATION FOR EXPORT OF COMPLETE INDUSTRIAL PLANTS

PRAHA II, VÁCLAVSKÉ NÁM. 56, CZECHOSLOVAKIA

POHLIG
CABLEWAYS

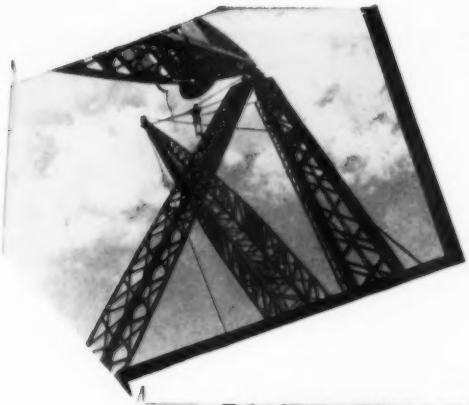


13 POHLIG – Cableways
with spans up to 2800 ft.
and lifting heights up to 900 ft.,
travelling speeds up to 1200 ft. per minute
and a carrying capacity
of up to 20 tons per each cableway
have been erected and commissioned
during the last 5 years
by our company
in Switzerland

J. POHLIG AKTIENGESELLSCHAFT · COLOGNE

From every point of view

BUTTERS DERRICKS

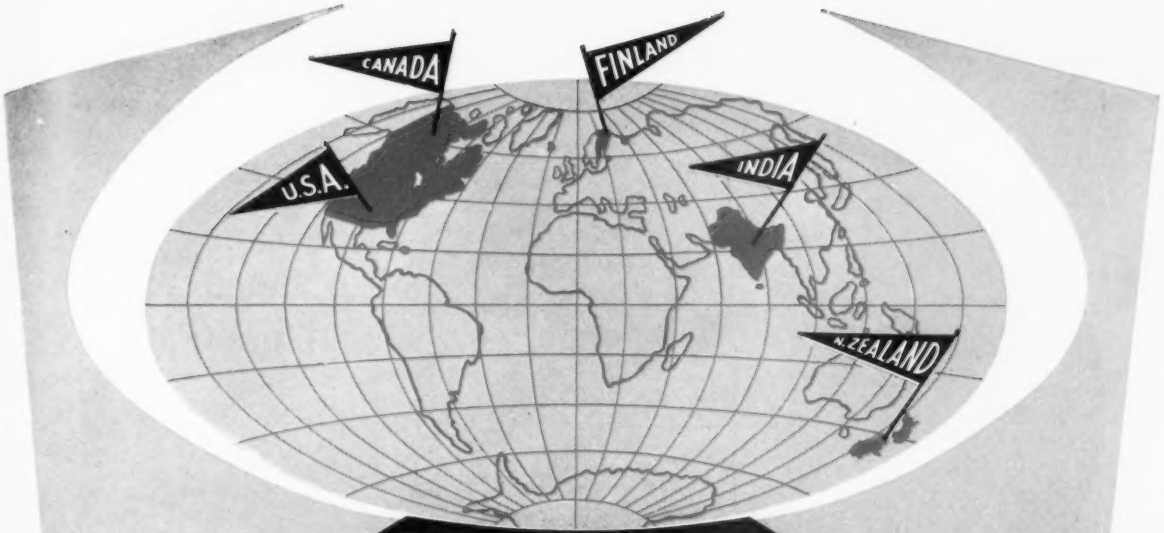


are second to none.....

Full vision of load, fool-proof jib interlock, machine-cut gears, ease of operation and maintenance, and robust construction to the most modern standards of design, contribute to the outstanding service provided by Butters Derricks. These cranes are made in all sizes and powers, and we shall be glad to submit details of standard models and to quote against requirements.

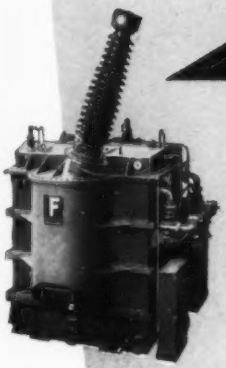
BUTTERS BROS. & Co. Ltd.

MACLELLAN STREET · GLASGOW, S.1
Phone: IBROX 1141 (6 lines) Grams: "BUTTERS, GLASGOW"
LONDON: THE CRANE WORKS, LONG LANE, HILLINGDON
MIDD'X *Telephone: UXBRIDGE 925 & 2288*
AND AT BIRMINGHAM AND NEWCASTLE



FERRANTI
TRANSFORMERS

FAMOUS THROUGHOUT THE WORLD



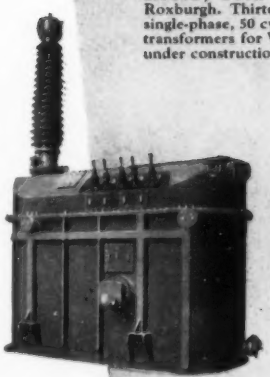
U.S.A. Nine 33,333 kVA, 230,000 volt single-phase Ferranti transformers are being supplied to the U.S. Army Corps of Engineers for the Garrison Dam Project, North Dakota, U.S.A. Three, forming the first 100,000 kVA bank, have been shipped.

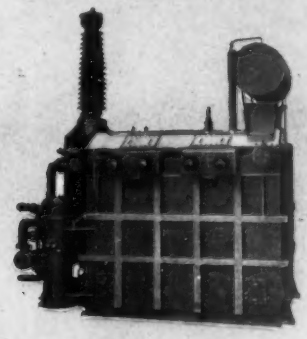
FINLAND Six 230,000 volt, three-phase Ferranti transformers have been ordered by the Imatra Power Company, Finland, for the Hikia Transforming Station and the Pyhäkoski Generating Station. Five are now in commission.

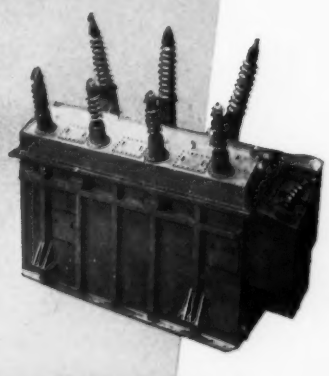
NEW ZEALAND Twenty-six Ferranti large power transformers have been ordered by the State Hydro-Electric Department of New Zealand. Thirteen 14,800 kVA, single-phase, 50 cycles, 11/220 kV transformers have already been supplied to Roxburgh. Thirteen 9,259 kVA, single-phase, 50 cycles, 11/220 kV transformers for Whakamaru are under construction.

CANADA Four 71,000 kVA, 301,400 volt single-phase Ferranti generator transformers and three 37,000 kVA, 275,000 volt step-down Ferranti transformers have been supplied to the Aluminum Company of Canada Limited for the Alcan Project at Kemano and Kitimat, British Columbia.

INDIA Three Ferranti 20,000 kVA, OFB, 3-phase, 50 cycles, 132/33.66 kV Transformers with on-load tap changing gear and two Ferranti 10,000 kVA, ON/OB, 3-phase, 50 cycles, 132/33 kV transformers with on-load tap changing gear have been supplied for the Damodar Valley Power Scheme in India.



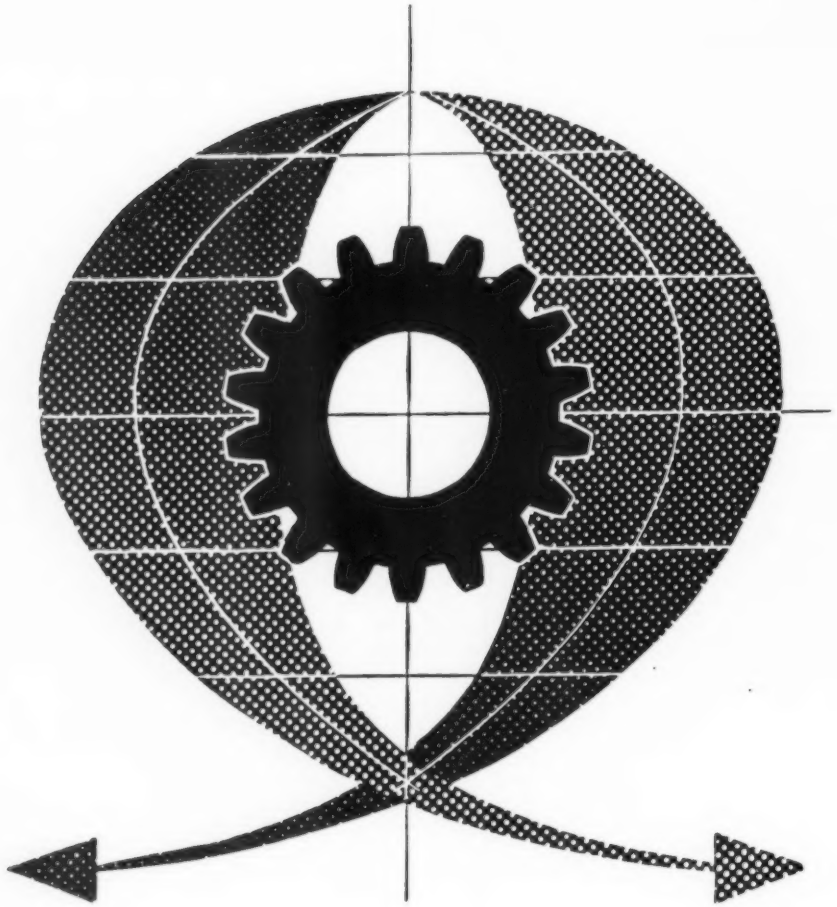




FERRANTI LTD · HOLLINWOOD · LANCS

London Office: KERN HOUSE, 36, KINGSWAY, W.C.2

FT146/2



THE LATEST TECHNICAL AND PRODUCTION DEVELOPMENTS

of the Czechoslovak engineering industry will be exhibited and demonstrated at the

2nd CZECHOSLOVAK ENGINEERING EXHIBITION

BRNO

8th to 30th SEPTEMBER, 1956

Billions

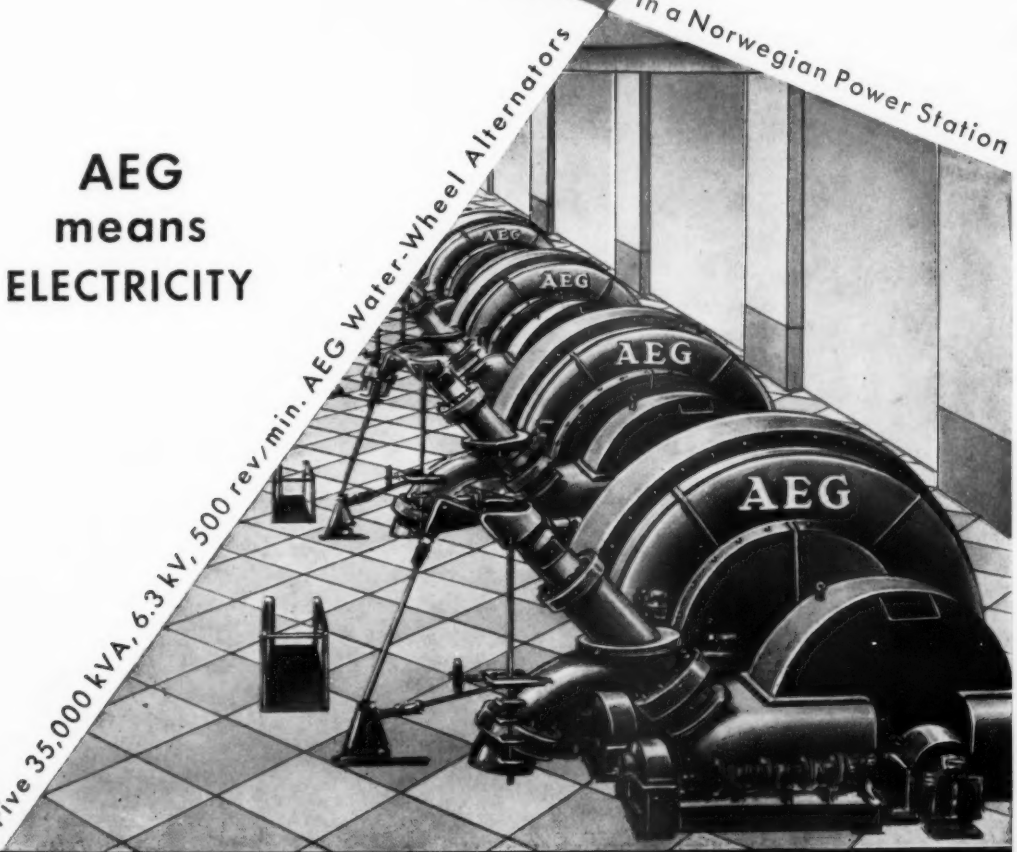
of Kilowatt-hours from

AEG

Hydro-Electric Generators

in a Norwegian Power Station

AEG means ELECTRICITY



Five 35,000 kVA, 6.3 kV, 500 rev/min. AEG Water-Wheel Alternators

6367e

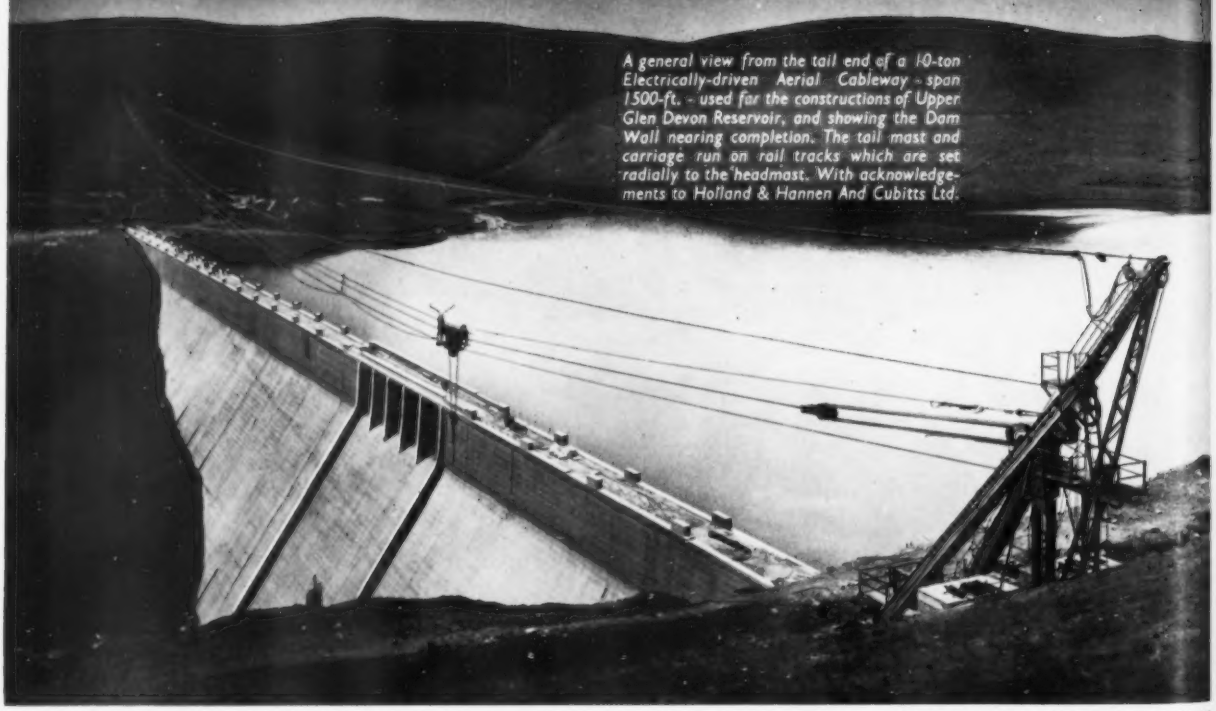
ALLGEMEINE ELEKTRICITÄTS - GESELLSCHAFT

Berlin (West) EXPORT DEPARTMENT Frankfurt (Main)

well on top of schedule

MOVEMENT of materials . . . . . that's the secret of meeting schedules on great projects. Getting the stuff in, putting the machinery on the job, - half the battle is won when movement is unhampered, when the equipment which handles the gear does so with unfailing reliability.
Henderson Cableways fit the description. Not only is each component built to the highest degree of engineering skill - Henderson Cableways are undoubtedly the most economical method of moving big loads on the majority of dam, barrage, bridge or viaduct contracts. Confirmation of this fact lies in the considerable number of cableways we have installed at vast projects throughout the world.

Henderson *CABLEWAYS*
lifelines to movement



A general view from the tail end of a 10-ton Electrically-driven Aerial Cableway - span 1500-ft. - used for the constructions of Upper Glen Devon Reservoir, and showing the Dam Wall nearing completion. The tail mast and carriage run on rail tracks which are set radially to the headmast. With acknowledgements to Holland & Hannen And Cubitts Ltd.

JOHN M HENDERSON AND CO LIMITED KINGS WORKS ABERDEEN

This 2,680′ Bridge River, British Columbia, Dominion of Canada, penstock was built by B. C. Electric. Of 75⅝″ O. D. steel pipe, it is Dresser-Coupled in 40′ lengths with maximum slope of 39½°. Uncovered except for one intermediate tunnel, it tested completely leakproof at 1000 psi.

6 ft. 3 and TROUBLE-FREE at 1000 psi

B. C. Electric installs 4th Dresser-Coupled penstock

Convinced of the advantages of Dresser Couplings, the B. C. Electric Company, since 1948, has installed four 100 per cent Dresser-Coupled penstocks at Bridge River, British Columbia. On all four projects, the use of Dresser Couplings resulted in faster completion of the line and assured permanently tight, maintenance-free joints. This meant earlier revenue from plant operation . . . uninterrupted service to power consumers.

Throughout the world, leading engineers and contractors recognize the superiority of the Dresser pipe joining method — permanent tightness, flexibility, simplicity, strength and economy.

Even highest pressure penstocks are faster and easier to install when Dresser Couplings are used. The need for special skills and expensive equipment is minimized. In many cases, a field crew of a few men can cut construction time from months to weeks through the use of Dresser Couplings. Work proceeds in any weather with wrenches the only tools needed.

Where required, high tensile steel permits thinner pipe walls and lower pipe weights. This means easier handling. In some cases, up to 25 per cent in weight is saved.

But a Dresser-Coupled penstock's most important advantage is permanence . . . it stays bottle-tight for life. The resilient gaskets built into every coupling assure positive sealing, eliminate expansion-contraction problems, permit joint deflections so the penstock may follow the natural contour of the right of way.

For your next penstock project, send for helpful, interesting engineering data on the successful and varied Dresser-Coupled steel penstock installations. Write Dresser Manufacturing Division, Bradford, Pa., U.S.A.

ONE OF THE DRESSER INDUSTRIES

MUCONE POWER STATION
No. 1, ITALY

PENSTOCKS IN COURSE
OF ERECTION

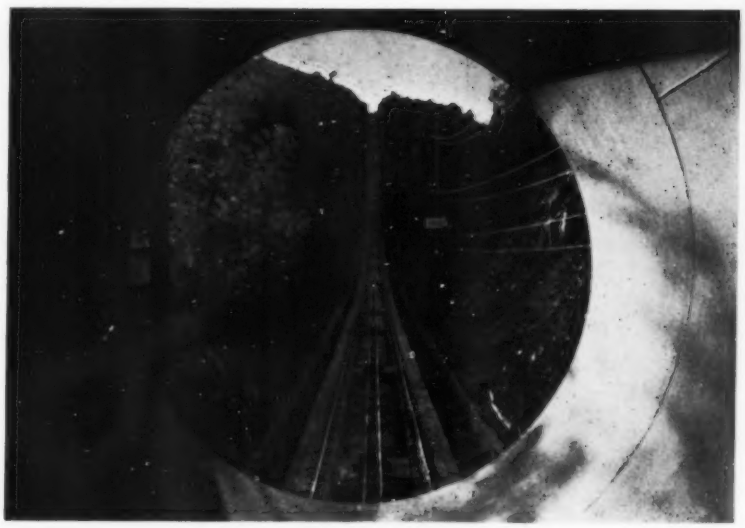
Head—752 metres
Diameter—2·50-2·20-2·00 metres

DESIGNERS AND MANUFACTURERS OF THE MOST MODERN AND POWERFUL HIGH PRESSURE PIPE-LINES WITH A WORLD WIDE REPUTATION

★

EARLY DELIVERY

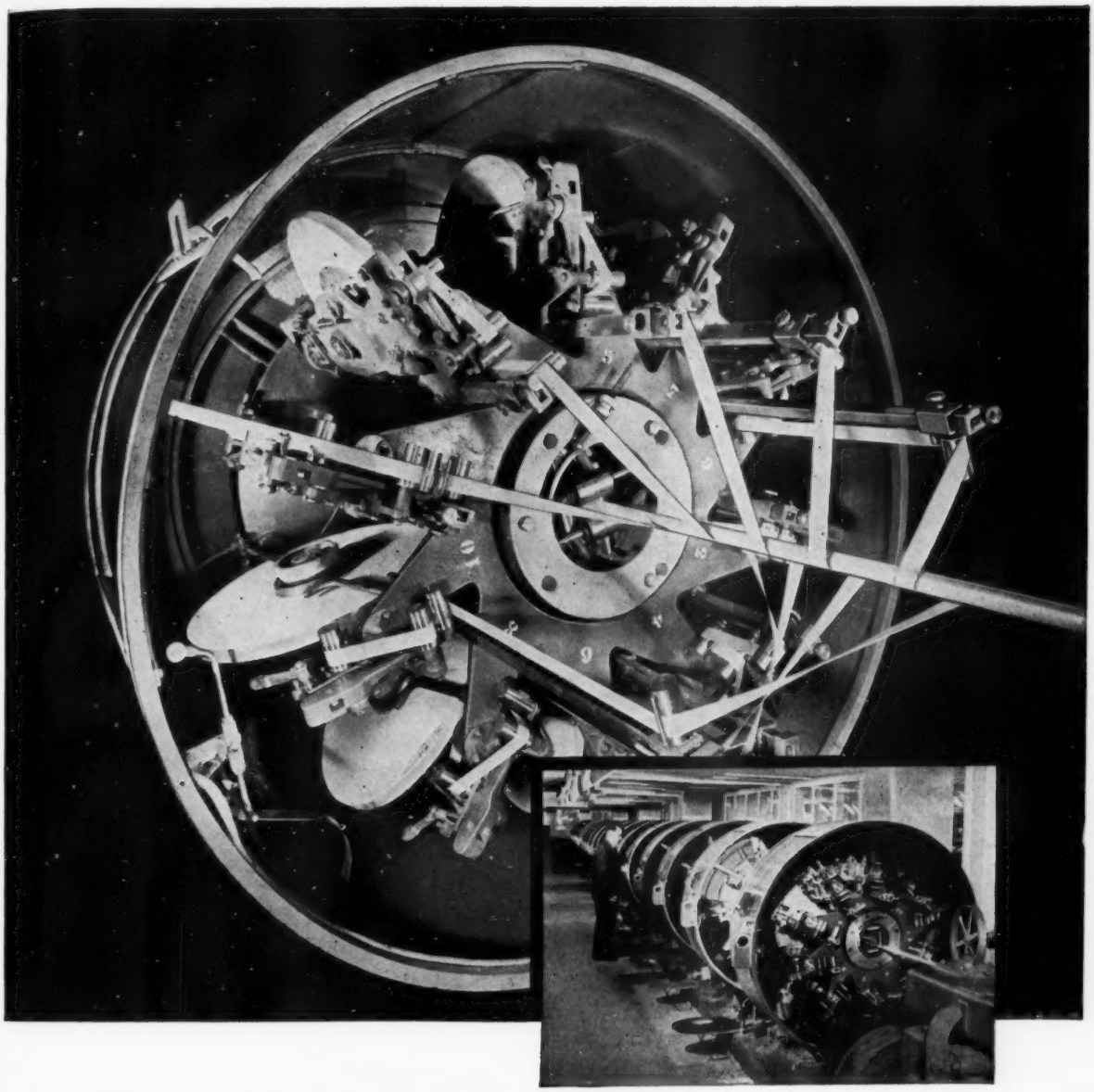
★



COFOR

SOC. CONDOTTE FORZATE, MILANO — VIA DELLA POSTA 8/10 MILAN, ITALY

Associated with Terni, Soc. per l' Industria e l' Elettricità, Terni, Italy
ETABTS, Bouchayer and Viallet, Grenoble, France
Soc. Dauphinoise d' Études et de Montages, Grenoble, France



More than a lap ahead

This specially designed paper-lapping machine, the first of its kind in the country, is housed in an air-conditioned enclosure.

With 20 reversible lapping heads, each capable of applying 10 papers, up to 200 layers of insulation can be applied simultaneously at controlled tensions.

Precision lapping in a controlled atmosphere is now our standard practice for all super-tension cables — a further guarantee of the reliability of Pirelli-General Cables supplied for the highest voltages.

PIRELLI-GENERAL

SUPER TENSION CABLES

PIRELLI-GENERAL CABLE WORKS LTD., SOUTHAMPTON

ASSOCIATED COMPANY OF THE GENERAL ELECTRIC CO. LTD.

Now it's packed for easier handling!
AWCO
ALUMINIUM ARMOUR TAPE
SIZE .250" x .030"
WEIGHT 7 lb.
LENGTH 800 ft. NOMINAL
AWCO ARMOUR TAPE SHOULD ALWAYS BE USED WITH ALL ALUMINIUM SILMALEC AND STEEL CORED ALUMINIUM CONDUCTORS
MANUFACTURED BY
ALUMINIUM WIRE & CABLE CO. LTD.
PORT TENNANT · SWANSEA · GREAT BRITAIN

made to measure for your convenience

The familiar 7 lb. coils of AWCO Aluminium Armour Tape are now packed in individual cartons, clearly labelled with the size— 0·250" x 0·030" (800 ft.) and 0·300" x 0·050" (400 ft.)

* AWCO Armour Tape is made from high purity (99.5%) aluminium, essential for binding aluminium or Silmalec conductors. Details are given in Folder No. O.T. 22.

Prevents damage in transit Keeps tape clean
Easy to handle Convenient to store
Clearly labelled for easy identification
Simplifies stock checking and control Prevents wastage

ALUMINIUM WIRE & CABLE CO. LTD.

Britain's Largest Manufacturers of Aluminium Wire and Conductors

Head Office & Works: PORT TENNANT, SWANSEA, GLAMORGAN

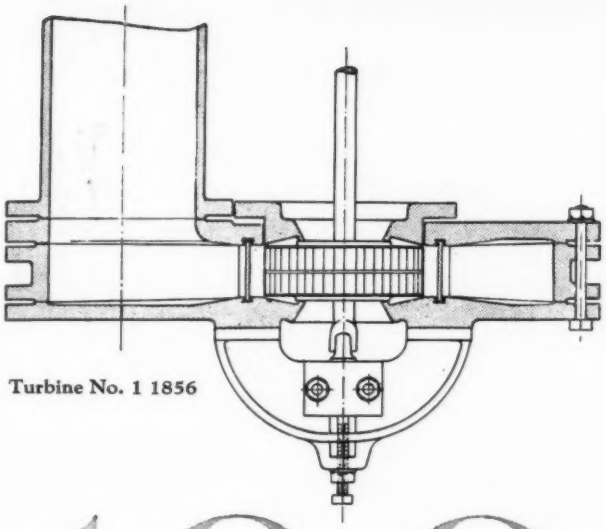
Sales Office: 30 CHARLES II STREET, ST. JAMES'S SQUARE, LONDON, S.W.1

Tel.: TRAfalgar 6441

A.P. 210/245

GILKES

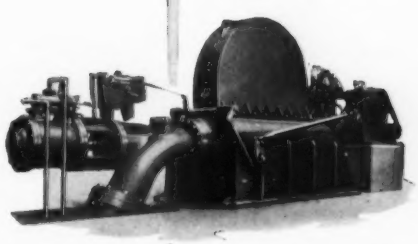
1856—1956



Turbine No. 1 1856

100 years' progress in water power

The drawing above shows our Water Turbine No. 1, manufactured in Kendal in 1856. It develops 5 horsepower and is still giving useful service. Since those early days, we have built over 5,400 turbines, and are the only firm in the United Kingdom which has been continuously building water turbines for a century. We have constructed water turbine governors since before 1900 and we were the first manufacturers to set up a permanent water turbine test plant in this country. Constant development work has kept us in the forefront of water turbine design; the "Gilkes" Turgo Impulse Wheel has a specific speed far higher than that of any other single jet impulse turbine; the "Giljet" Governing System gives unique regulation for Francis turbines with long pipelines. The 9,000 H.P. Pelton Wheel shown in the lower illustration is typical of our modern designs; it operates in the High Andes of Bolivia, utilising a head of 2,600 ft.



9,000 H.P. Water Turbine

GILBERT GILKES & GORDON LTD

Water Turbine and Pump Manufacturers

KENDAL & LONDON · ENGLAND

G.68

Now under construction, the Karnafuli Project marks an important forward step in the economic development of East Pakistan. Designed and engineered by the International Engineering Company, this multi-purpose dam and powerplant will ultimately generate 160,000 kw of hydroelectric power to meet vital industrial needs.

Effective flood control will benefit the entire Karnafuli River Basin area, also permitting reclamation of land for agriculture and other purposes. A system of locks will improve river navigation, aid in the extraction and shipping of forest products, create better facilities for commercial fishing. By 1960, estimated financial benefits from Karnafuli will total nearly 44 million rupees annually . . . over 50 million in 1965.

International Engineering has for years specialized in the design and engineering of water and power projects like Karnafuli. Their complete services — from preliminary survey to engineering supervision of construction — are available to governments and private industry worldwide.

INTERNATIONAL ENGINEERING COMPANY, INC.

74 New Montgomery Street • San Francisco, California, U. S. A.
A subsidiary of Morrison-Knudsen Company, Inc.

FULL INFORMATION about the International Engineering Company is contained in an illustrated 16-page brochure . . . write to Dept. G-2 for your copy today.

Representatives: **ENGLAND**: 47 Victoria Street, London S.W.1 **CANADA**: 1111 W. Georgia Street, Vancouver, B.C. **TURKEY**: Morrison-Garanti, Box 281, Adana **PAKISTAN**: P.O. Box 4851, Karachi

Vevey

Hydraulic Turbines,
complet equipement for
Hydro-electric Power
Plants.

Vevey Engineering Works Limited

Vevey / Switzerland

SOURCES OF POWER

Water

A swollen raindrop rolls off a leaf and
falls on a leaf below. On the impact, the
lower leaf is deflected; for an instant it
becomes the blade of a paddle-wheel,
for an instant it is driven.
From the top of a giant cataract to
the power-house below, a torrent
of water is directed down a man-made
flume to whirl the blades of a turbine.
The turbine is geared to a dynamo.
At this point, where water power becomes
electrical power, Crompton Parkinson
take over. There have been few major
developments in the control of electricity
with which this Company has not been
associated. And so long as there is
electricity, and from whatsoever source it
is made, Crompton Parkinson will continue
to develop machinery and equipment
for its transmission, measurement,
regulation and utilisation.

ELECTRICAL EQUIPMENT

Crompton Parkinson
LIMITED

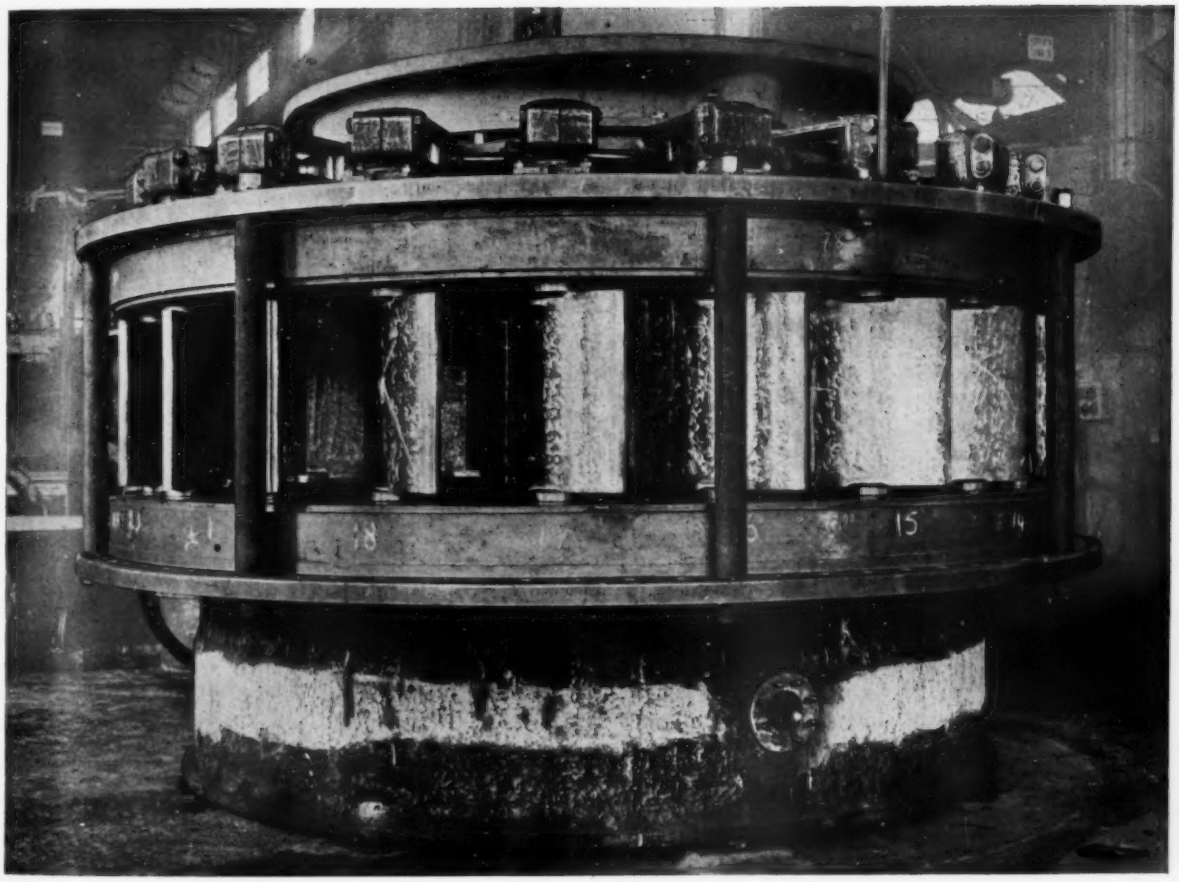
MAKERS OF ELECTRIC MOTORS OF ALL KINDS · ALTERNATORS & GENERATORS
SWITCHGEAR · TRANSFORMERS · CABLES · INSTRUMENTS · LAMPS · LIGHTING EQUIPMENT
STUD WELDING EQUIPMENT · BATTERIES · TRACTION EQUIPMENT · CEILING FANS

CROMPTON PARKINSON LIMITED has branches and agencies in all parts of the world. *If you cannot readily make contact, please write direct to us at* CROMPTON HOUSE, ALDWYCH, LONDON, W.C.2, ENGLAND · *Overseas Telegrams:* CROMPARK LONDON

FRANCO TOSI S.p.a ★ LEGNANO (ITALY)

HYDRAULIC TURBINES

KAPLAN ★ FRANCIS ★ PELTON ★ GOVERNORS ★ VALVES

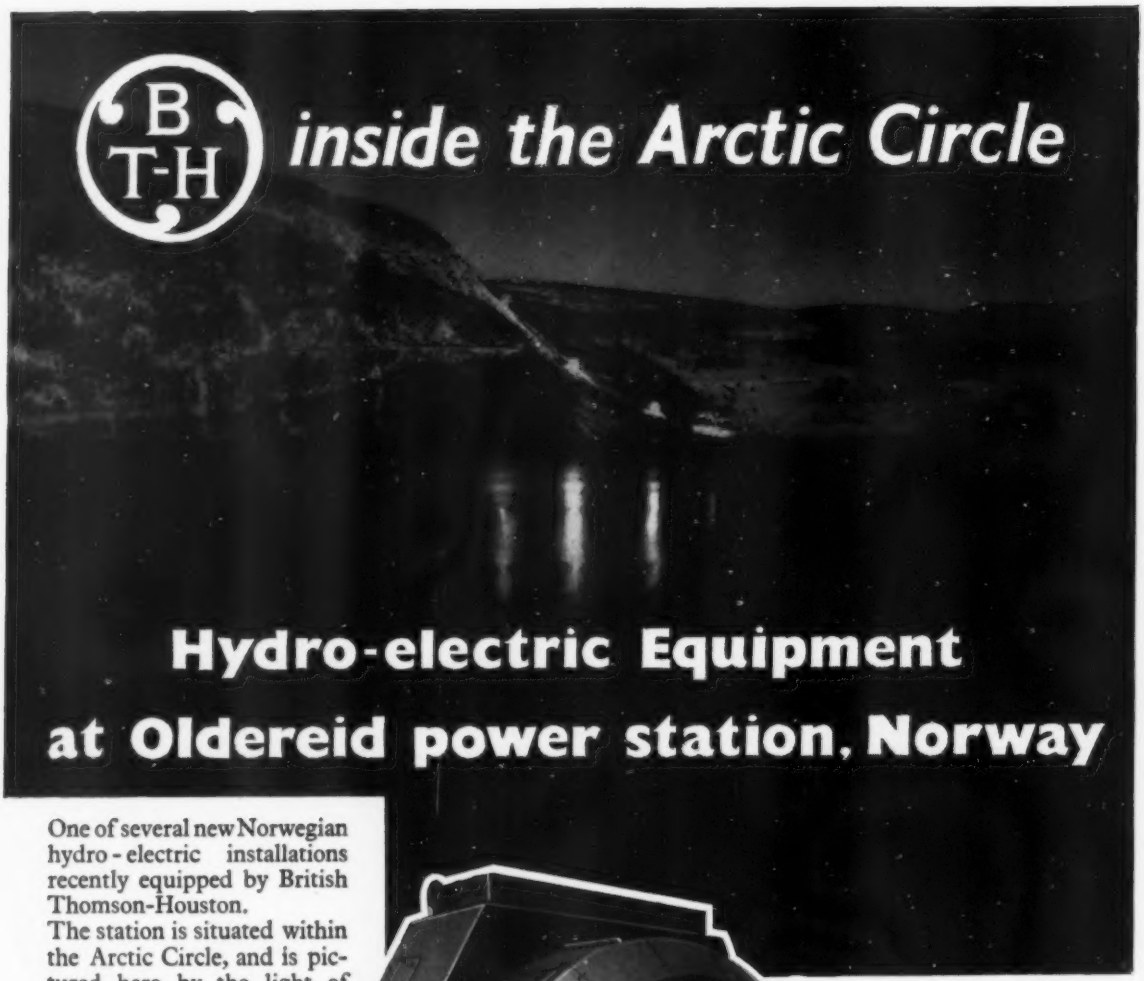


Upper and lower casings with deflector vanes and operating mechanisms.

ELECTRICITÉ DE FRANCE — PARIS

ST. PIERRE COGNET HYDRO-ELECTRIC STATION

Francis turbine rated for 46,500 kW. Capacity 60 cu.m./sec. Head 88 mt. Speed 214 r.p.m.



B T-H

inside the Arctic Circle

Hydro-electric Equipment
at Oldereid power station, Norway

One of several new Norwegian hydro-electric installations recently equipped by British Thomson-Houston.
The station is situated within the Arctic Circle, and is pictured here by the light of the midnight sun.

BTH horizontal waterwheel-alternator (rated 14,000 kVA, 6.6 kV), now installed at Oldereid Power Station.

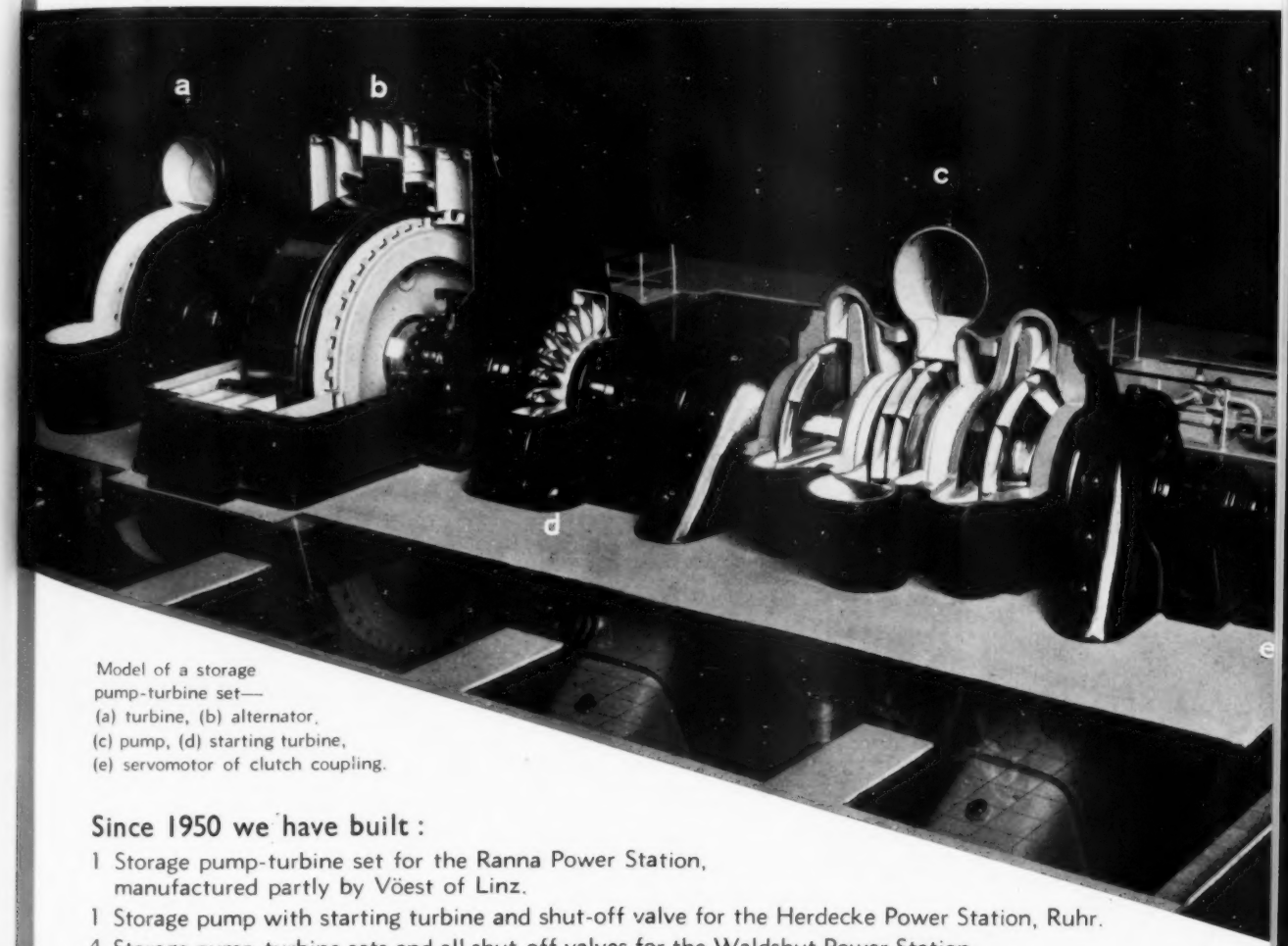
BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON COMPANY LIMITED · RUGBY · ENGLAND

Member of the AEI group of companies

A4799

VOITH'S background of long and extensive experience in the design, manufacture and supply of pumped storage plants is at your disposal.



Model of a storage pump-turbine set—
(a) turbine, (b) alternator,
(c) pump, (d) starting turbine,
(e) servomotor of clutch coupling.

Since 1950 we have built:

1 Storage pump-turbine set for the Ranna Power Station, manufactured partly by Vöest of Linz.
1 Storage pump with starting turbine and shut-off valve for the Herdecke Power Station, Ruhr.
4 Storage pump-turbine sets and all shut-off valves for the Waldshut Power Station.
1 Storage pump-turbine set and shut-off valves for the Gobantes Power Station (Spain).
1 Storage pump for the Rodund Power Station, ILL (Austria), in conjunction with Voith of St. Pölten.
2 Storage pump-turbine sets with all shut-off valves for the Reisach Power Station (see illustration).
1 Storage pump-turbine set with shut-off valves for the Brattingfoss Power Station (Norway).

We have on order:

2 Storage pumps and shut-off valves for the Ottenstein Power Station (Austria), manufactured to a large extent by Vöest of Linz. Pump input 12,500 H.P. each.
2 Storage pump-turbine sets and shut-off valves, as well as 3 torque converters for the Lünersee Power Station (Austria). Turbine output 62,800 H.P., Pump input 74,000 H.P.
2 Storage pump-turbine sets and shut-off valves for the Happurg Power Station (Nürnberg).
Remodelling of 2 storage pumps for the Häusern Power Station of the Schluchseewerk.

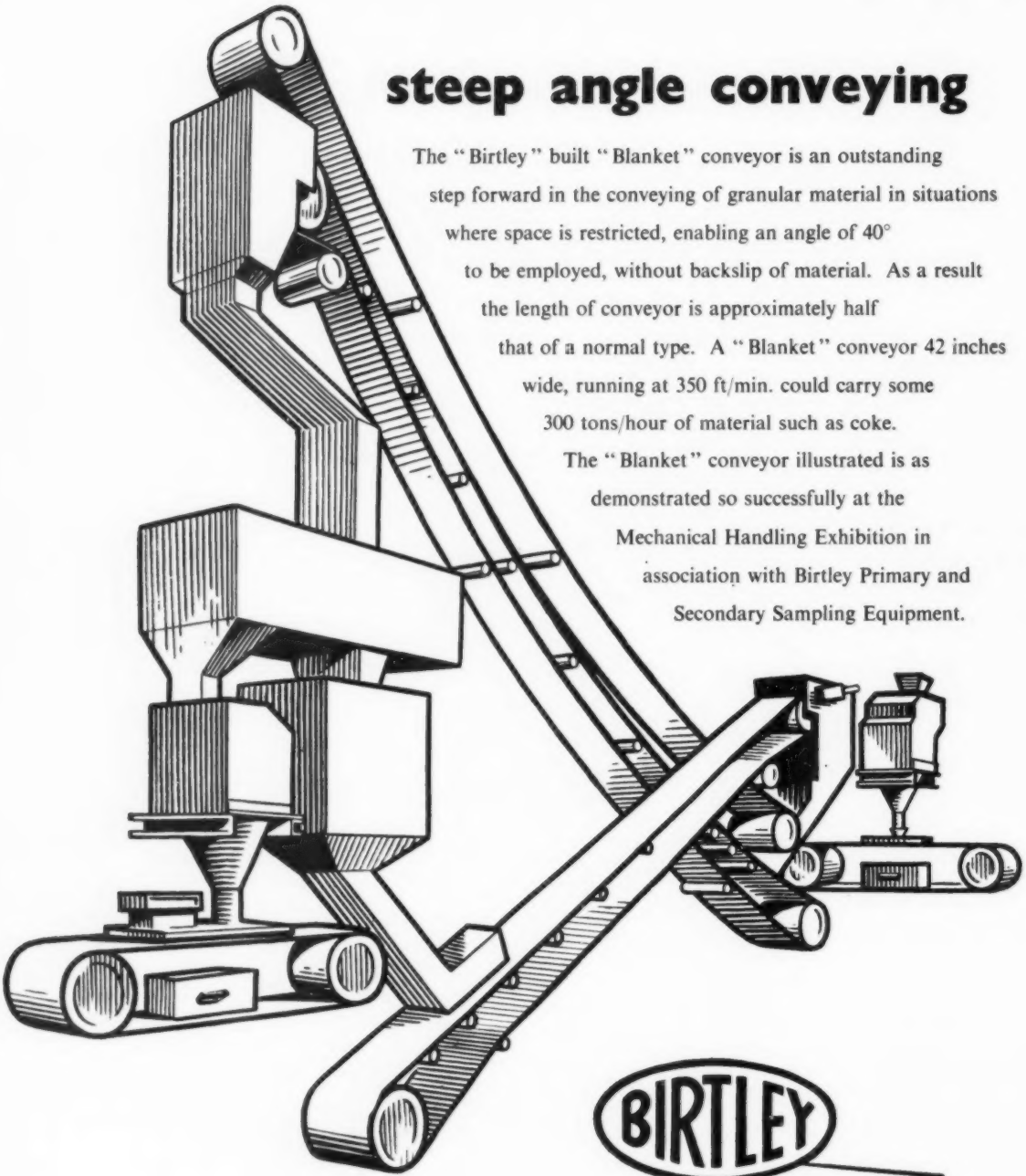
We have extensive resources of modern laboratories, testing equipment and up-to-date manufacturing facilities. Our staff possesses wide experience and high technical skill in the design, construction and erection of most progressive hydraulic equipment that is efficient and dependable in operation. Our experts are at your service, without obligation, to advise and assist you with technical information and preliminary estimates.

J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY

steep angle conveying

The "Birtley" built "Blanket" conveyor is an outstanding step forward in the conveying of granular material in situations where space is restricted, enabling an angle of 40° to be employed, without backslip of material. As a result the length of conveyor is approximately half that of a normal type. A "Blanket" conveyor 42 inches wide, running at 350 ft/min. could carry some 300 tons/hour of material such as coke.

The "Blanket" conveyor illustrated is as demonstrated so successfully at the Mechanical Handling Exhibition in association with Birtley Primary and Secondary Sampling Equipment.



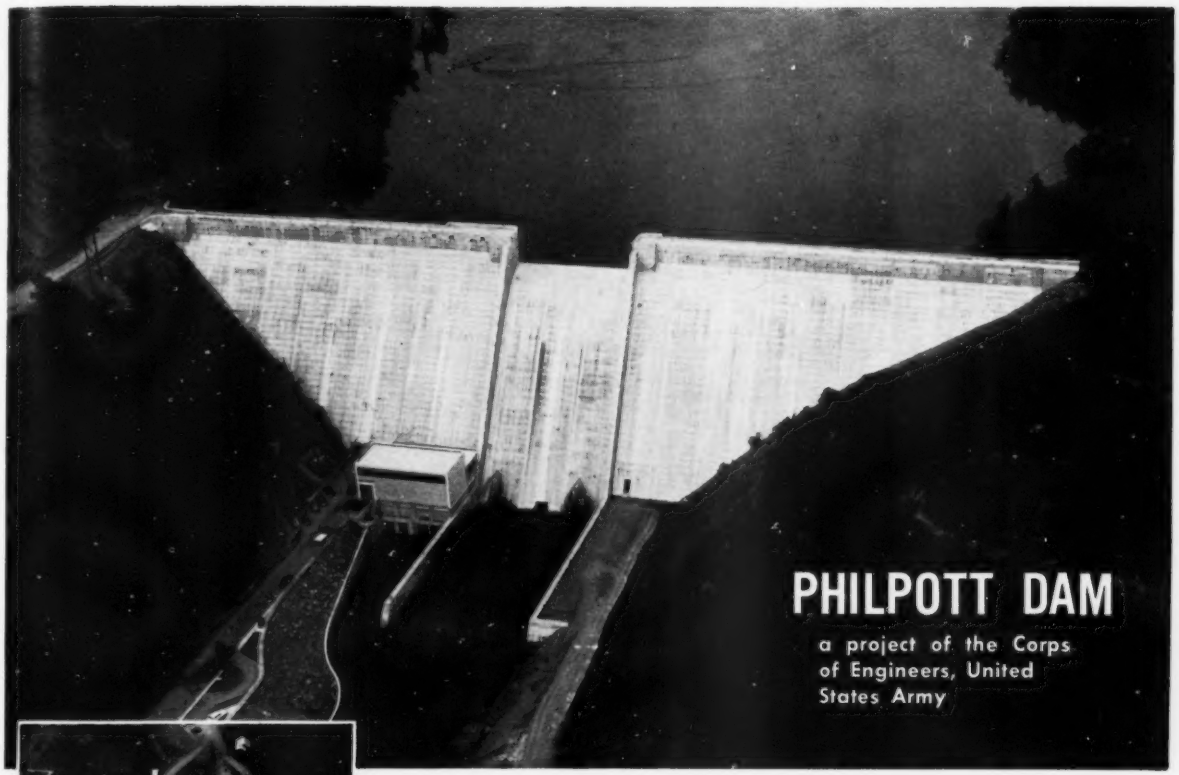
BIRTLEY
MATERIALS HANDLING

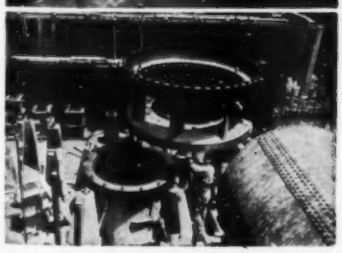
THE BIRTLEY COMPANY LIMITED

BIRTLEY · COUNTY DURHAM · ENGLAND

TEL: BIRTLEY 110 (4 LINES) GRAMS: BIRTLEY NEWCASTLE

3343





Another Outstanding Installation of **Leffel Hydraulic Turbines**

Philpott Dam, a recent Corps of Engineers, United States Army, project on the Smith River in Henry and Franklin Counties, Virginia, is a site of another outstanding installation of efficient dependable Leffel turbines. The Philpott project was constructed for flood control and hydroelectric power generation. It is one unit of a comprehensive reservoir system planned for the Roanoke River basin.

Three Leffel turbines were installed at the Philpott power plant. Two are each rated at 9,400 h.p. under 152 ft. net head, at a speed of 227 r.p.m.; and the third is rated 860 h.p. at 720 r.p.m.

The view above shows the completed project. The views at the left show the project under construction, the spiral casing for one turbine in place, and a stay ring being lowered into place over the draft tube.

Other Leffel installations are dependably and efficiently producing power from water in this country and in all parts of the world. Leffel engineers are waiting to put their 94 years of experience with water power to work for you, whether your project is a completely new installation, or an expansion or rehabilitation of existing facilities.

Write today for literature describing Leffel turbines for all hydraulic power requirements and showing a wide variety of outstanding Leffel installations.

1095-E

FOUNDED IN 1862

THE JAMES LEFFEL & CO.

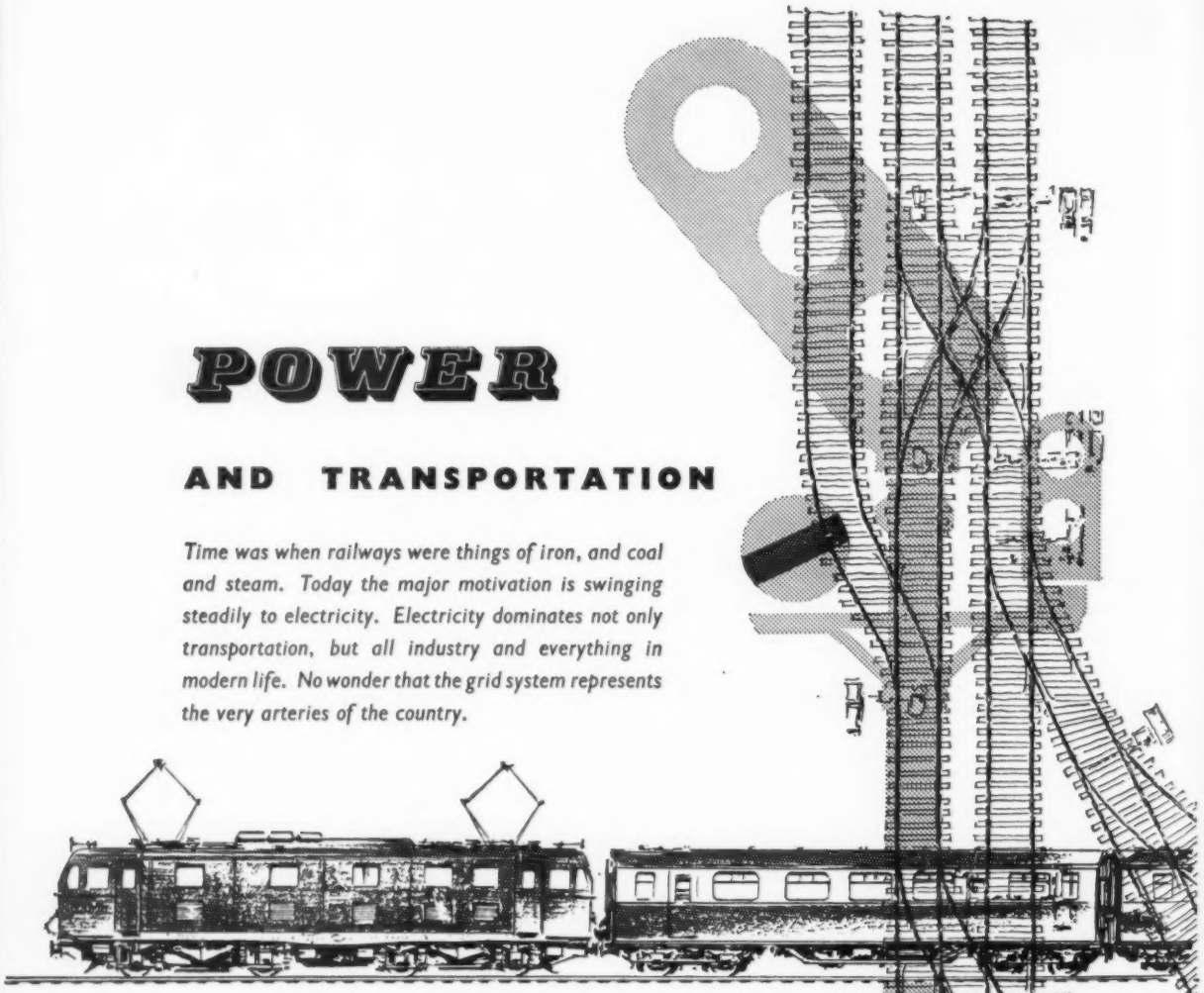
DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 94 YEARS

POWER

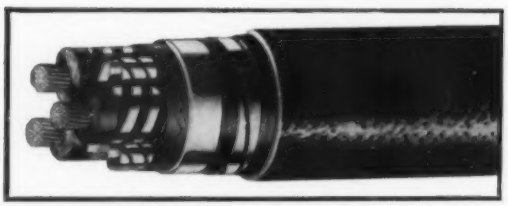
AND TRANSPORTATION

Time was when railways were things of iron, and coal and steam. Today the major motivation is swinging steadily to electricity. Electricity dominates not only transportation, but all industry and everything in modern life. No wonder that the grid system represents the very arteries of the country.



Wherever electricity comes from and wherever it goes, Henley cables contribute significantly towards its safe and certain transmission. All the Henley experience and resources in the design and manufacture of supertension cables up to 132 kV are at your disposal.

POWER CABLES by HENLEY



132 kV 3-CORE OIL-FILLED CABLE

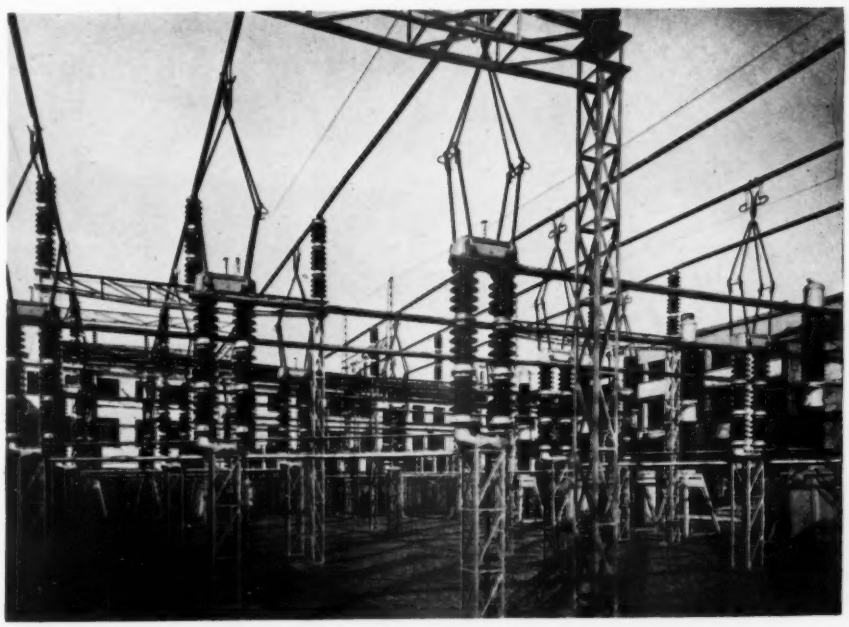
BY APPOINTMENT TO HER MAJESTY THE QUEEN ELECTRIC CABLE MANUFACTURERS

W. T. HENLEY'S TELEGRAPH WORKS CO. LTD., 51-53 HATTON GARDEN, LONDON, E.C.1

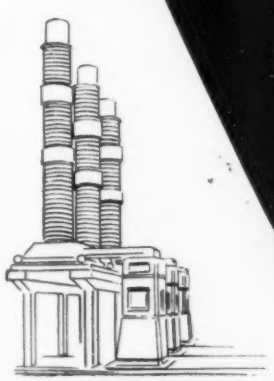
SCARPA & MAGNANO

Società per Azioni - Cap. Versato L. 200.000.000

SAVONA - MILANO



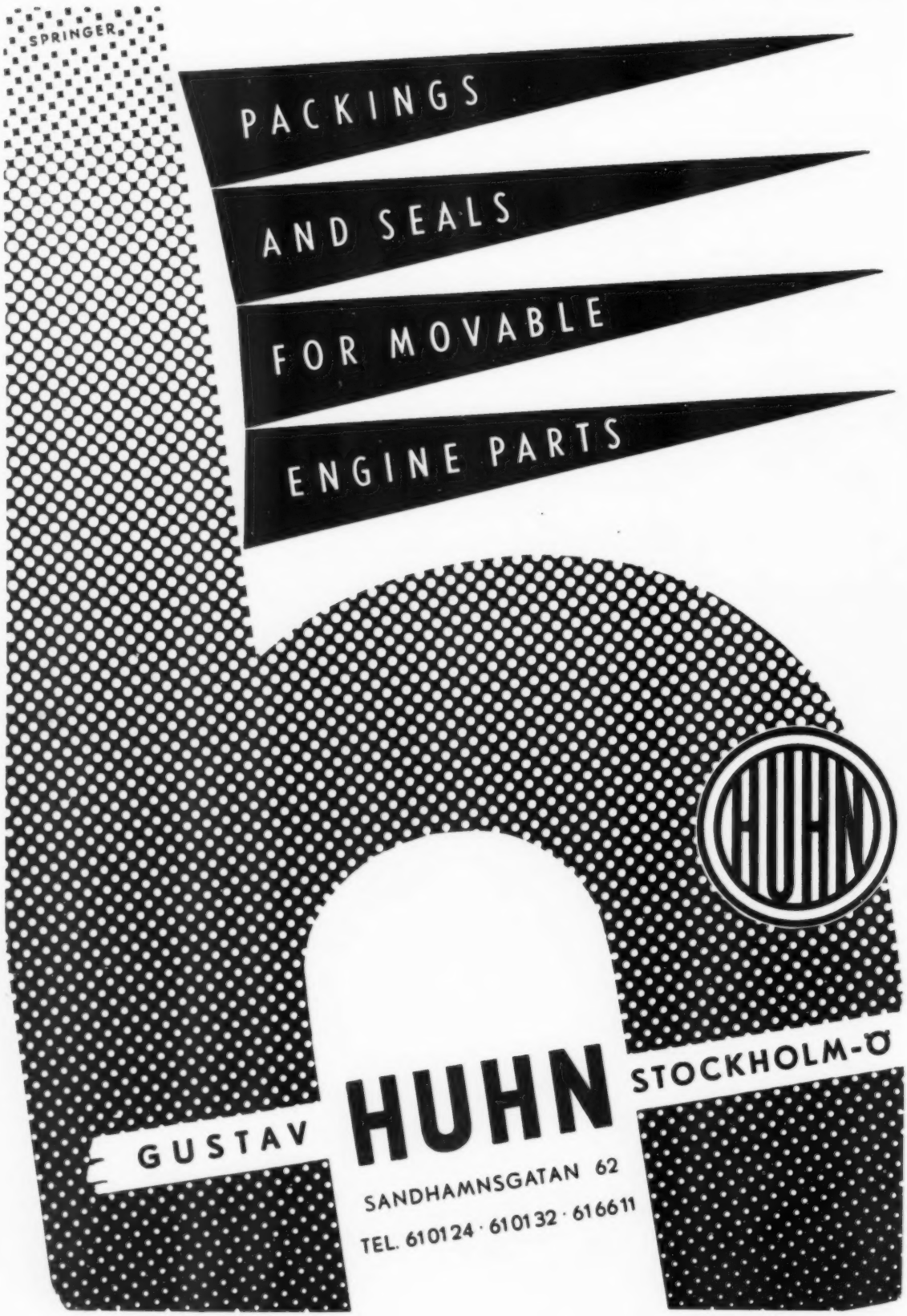
150 kV 600 Amps pantograph isolators installed at an Italian plant.

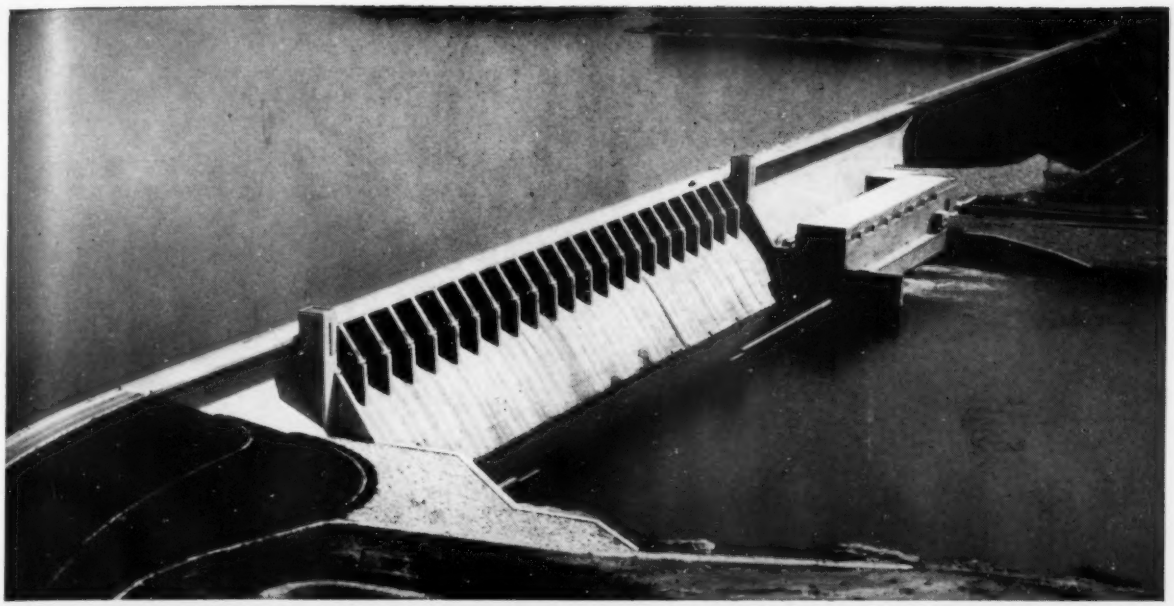


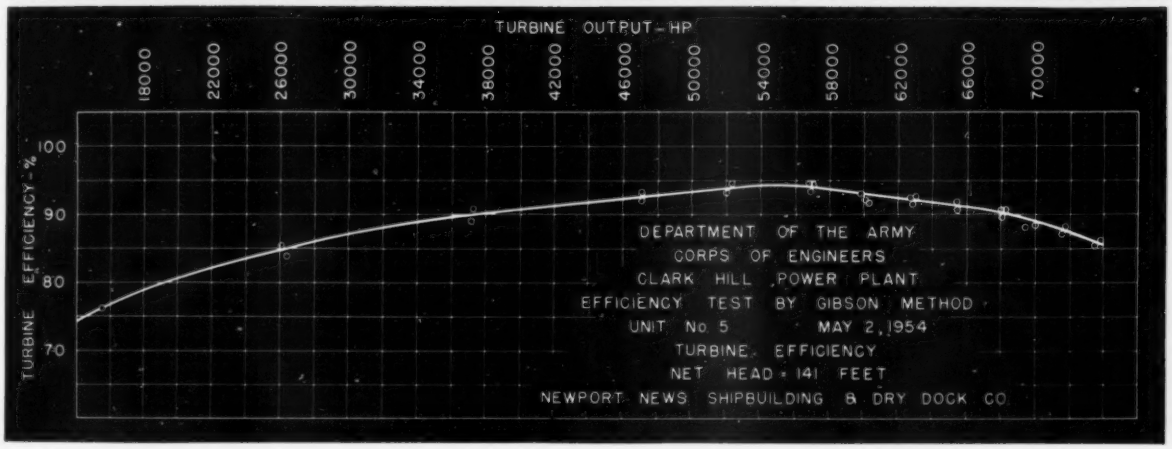
SM

Electrical switchgear for middle and high voltages, from 10 up to 220 kV indoor and outdoor installation

Works : SAVONA, V. Fiume 2 - Ph. 20159 - 20741 - 21230 • Cml. Management : MILAN, V. A. Manzoni 12 - Ph. 708251


SPRINGER
PACKINGS
AND SEALS
FOR MOVABLE
ENGINE PARTS
HUHN
GUSTAV
HUHN
STOCKHOLM-Ö
SANDHAMNSGATAN 62
TEL. 610124 · 610132 · 616611





Maximum efficiency of 94.1%

Reflects advanced practices at Newport News

THE GRAPH shows performance of a 55,000 horsepower turbine, one of seven such units built by Newport News for the Clark Hill Power Plant (see photo).

Shape of the curve is typical . . . not exceptional . . . for Newport News turbine performance. Regular, uniform, showing no-cut-off at full load, it indicates consistent delivery and stable operation.

And especially, experience in design and model testing.

At Newport News, turbine runners are continually being designed and redesigned for improvements in performance. And often upon receiving a contract for turbines, a model setting is built and complete tests made. So far, Newport News has filled turbine contracts with an aggregate rated output in excess of 7,000,000 horsepower.

Penstocks, spiral casings, valves, pumps, rack rakes and other essentials are also designed and built by Newport News. Our illustrated booklet, "WATER POWER EQUIPMENT," will be sent to you upon request.

Engineers . . . Desirable positions available at Newport News for Designers and Engineers in many categories. Address inquiries to Employment Manager.

Newport News

Shipbuilding and Dry Dock Company
Newport News, Virginia

why don't you talk to the people at Harland?

They are in the forefront of centrifugal pump, hydro-electric and rotating electrical machinery manufacture. In over fifty years they have tackled many thousands of electrical and hydraulic problems. The name Harland is famous in the world's waterworks industries and wherever water, hot or cold, is to be pumped. It is equally well known to users of electric motors and generators and in recent years Harland hydro-electric plant has been installed in every continent in the world. Their engineers are at your service to assist you to solve your problems.

H A R L A N D

CENTRIFUGAL PUMPS · WATER TURBINES · ROTOVALVES
ELECTRIC MOTORS AND GENERATORS · DESCALING PLANT

THE HARLAND ENGINEERING COMPANY LIMITED

ALLOA, SCOTLAND · Phone: ALLOA 390/5 Grams: ELECTRIC, ALLOA, SCOTLAND
London Office: HARLAND HOUSE · 20 PARK STREET, W.1. Phone: GROSVENOR 1221
Branches at: Bristol, Glasgow, Leeds, Timperley (Cheshire), Newcastle-on-Tyne, Nottingham, Wolverhampton & Overseas

P2260

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

Annually 35 shillings by post. Single Copies 2s. 6d.

Volume 8 Number 7

CONTENTS FOR JULY, 1956

Editorial: Europe's Energy Prospects - - - 243

Editorial Notes - - - - - - 244

The Sir Adam Beck-Niagara G.S. No. 2 - - - 246
By Richard L. Hearn, B.A.Sc., D.Eng.

The 1956 CIGRE Conference—I - - - 255

Tidal Power—II - - - - - 259
By Dr.-Ing. Gerhard Wickert

The New Stations of the Krångede Power Company—I - 264

Calculating Flow Through Turbines—II - - 269
By Sigfrid Andersson

Novel Fish-Collecting Facilities - - - 276

Short Articles: Harland Expansion Programme—Butterfly Valves for Eildon—New International Harvester Crawlers - - - - - - 277

Abstracts from the World Technical Press - - 280

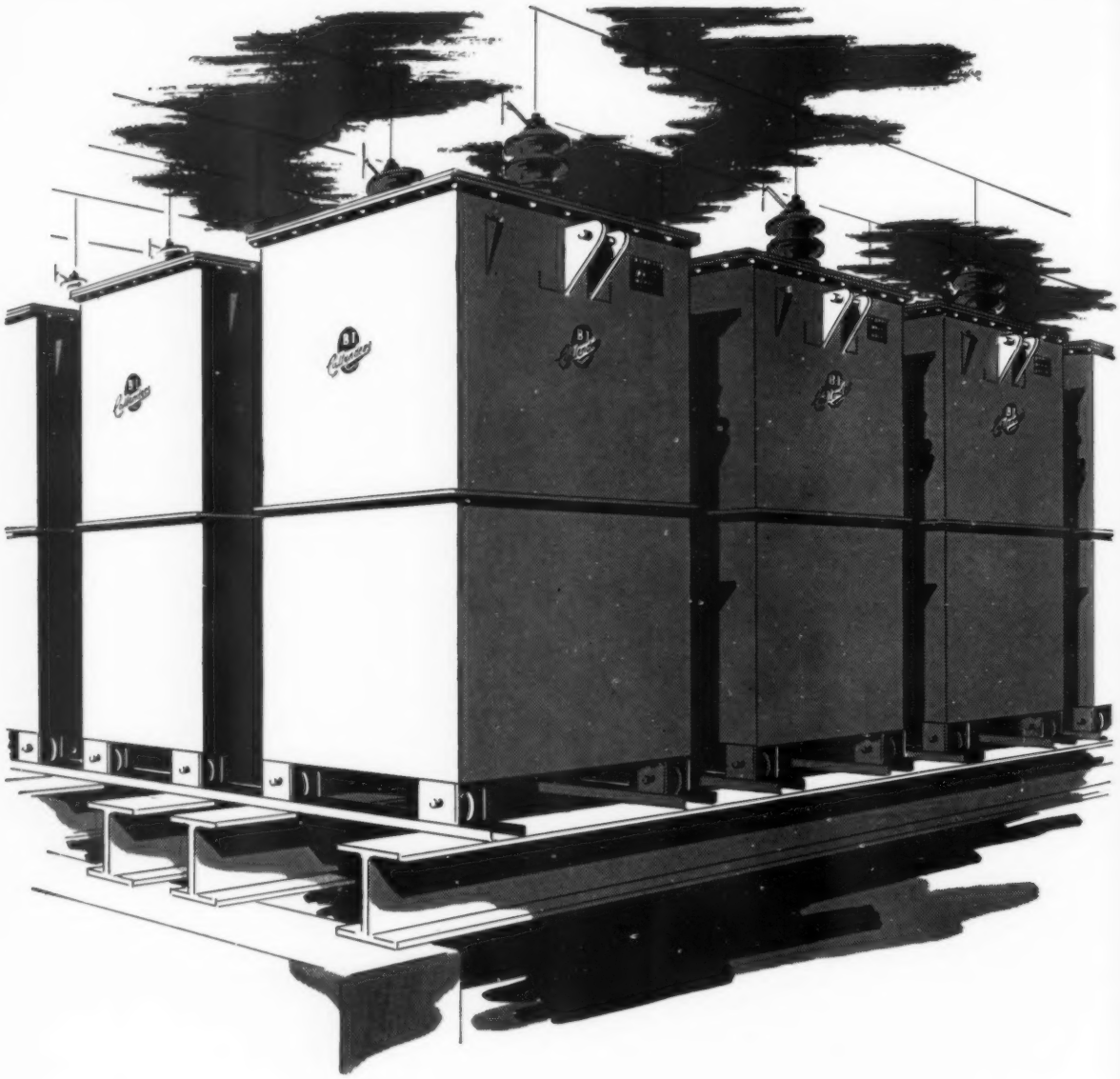
Editor: H. STOREY, M.C., B.Sc., M.I.M.E.

PUBLISHED BY TOTHILL PRESS LIMITED

33 Tothill Street, Westminster, London, S.W.1

Telegrams: Trazette, Parl, London. Telephone: Whitehall 9233 (20 lines)

MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101
BIRMINGHAM: 90 Hagley Road, Edgbaston. Telephone: Edgbaston 2466
NEWCASTLE-ON-TYNE: 21 Mosley Street. Telephone: 22239
GLASGOW: 87 Union Street. Telephone: Central 4646
LEEDS: 70 Albion Street. Telephone: 27174
BRISTOL: 8 Upper Berkeley Place, Clifton. Telephone: Bristol 21930



When VARS are in question

BICC POWER CAPACITORS

are the answer...

Details of all types of BICC Capacitors are available on request.

They are supreme in efficiency and reliability in all climates

BI Callender's **BRITISH INSULATED CALLENDER'S CABLES LIMITED** 21 BLOOMSBURY STREET, LONDON, W.C.1

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Europe's Energy Prospects

A DISTURBING picture of Europe's energy prospects up to 1975 is presented in a report* prepared by a group of experts on behalf of the O.E.E.C.; it is that of a rising consumption that will progressively outstrip anticipated indigenous development and will make Europe increasingly dependent on imported energy. The report itself is a masterly document—as we should expect from the membership of the Commission that prepared it, for the experts include some of the best brains in Europe under the chairmanship of Sir Harold Hartley, Chairman of the World Power Conference.

Forecasts of energy consumption are notoriously open to unforeseen contingencies, and one can only base forecasts on known trends, but the Commission has correlated the results of no less than four independent means of forecasting in order to reach its final assessment. The term "energy" has been taken to include the requirements of heating and transport as well as of power, and, expressed in million tons of coal equivalent, the mean forecasts are as follows: 1955 (base year), 730; 1960, 840; 1975, 1200. As against these figures, the indigenous production for 1955 was 584 million tons, and the anticipated figures for 1960 and 1975 are respectively 645 and 755 million tons of coal equivalent. Thus the deficiencies for these years to be made up by imports, are: 1955, 146 million tons (20%); 1960, 195 million tons (23%); 1975, 445 million tons (37%). In 1975 these imports would represent $5,000 million even at present prices, and it is fairly obvious that prices will rise during this period.

TABLE I—INDIGENOUS PRODUCTION

	1955	1960	1975
Coal	478	500	520
Lignite	31	35	35[1]
Hydro power	57	75	130
Crude oil	13	25	50
Natural gas	5	10	20
	584	645	755

[1] This might rise to 45 million tons of coal equivalent

The indigenous production for the years under consideration is broken down into its various sources in Table I, expressed in million tons of coal equivalent.

Without in any way minimising the ultimate importance of nuclear energy, the report is at pains to point out that the popular misconception that nuclear energy will make large contributions in the near future is seriously prejudicing the immediate need for development in the coal and other energy industries. It is estimated, in fact, that in 1975 the contribution of nuclear fuels is unlikely to exceed 8 per cent. of the energy requirements of Western Europe. Later, of course, nuclear energy will make a rapidly increasing contribution.

TABLE II—FORECASTS OF PRODUCTION OF ELECTRICAL POWER IN 1960 AND 1975

	1955	1960	1975	
			Low	High
Hydro production	140	185	300	350
Nuclear production	—	—	200	200
Thermal production	210	295	550	850
Total production..	350	480	1050	1400

Confining attention to estimated production of electrical power, the forecasts are as given in Table II, expressed in trillion-watt-hours.†

In the light of all these estimates, the Commission emphasises that coal will remain the mainstay of the energy economy of Western Europe for many years. This is evidently regarded by the Commission as its most important single conclusion, and the position and prospects of the coal industry are subjected to careful consideration, particularly in view of the fact that the prosperity of the industry depends upon long-term investment.

This conclusion is not to be regarded as in any way prejudiced, but arises from an objective analysis of trends. There is no hint in the report that the Commission is at all blind to the potentialities of hydro

* Europe's Growing Needs of Energy—How can they be met?". Published by The Organisation for European Economic Co-operation, 2 rue André-Pascal, Paris XVI. Price 8s., $1.25, 400 F.fr.

† TWh = 1,000,000,000 kWh.

power, and indeed, one of its conclusions is that additional effort must be devoted to the harnessing of undeveloped hydro resources. It points out that since water power is a capital energy resource, and under favourable conditions provides cheaper electricity than thermal stations, it is obviously desirable that this resource should be developed rapidly. The different characteristics of thermal, nuclear, run-of-river, and storage hydro plants are shown to contribute to an economic optimum obtainable by interconnecting these various types of plant. Thus, nuclear and run-of-river and the newer steam power stations will be used for base loads, whereas the older steam stations, gas turbines, and storage hydro plants (including pumped-storage) will be used mainly for peaks.

Nevertheless, the Commission considers that by 1975 the hydro potential of Western Europe will be approaching the limit of economic exploitation. There is some substance in this warning, for the problem is already beginning to loom in certain countries primarily dependent on hydro-electric power, and increased attention is being paid to the possibilities of thermal and nuclear resources, even if only to safeguard against the comparatively distant future. On the other hand, revised assessments of hydro potential, advances in constructional techniques, and changing economics, always tend to improve upon even the most optimistic forecasts where hydro power is concerned.

In any case, it is very difficult to generalise on a situation over a continent in which the pattern of resources varies so widely from country to country as it does in Europe. This variation is admirably brought out in an appendix to the report, which summarises the energy situation and prospects in each member country. Thus, Italy is the largest European producer of hydro power, with 29·4 TWh in 1954, but Norway, with an output of 21·8 TWh, relies on hydro power to the greatest extent and possesses the greatest reserves. France divides its electricity production almost equally between thermal (22 TWh) and hydro (24 TWh), whereas Great Britain's proportions are 93 TWh thermal and 2·2 TWh hydro.

One of the significances of the European situation as revealed in this report is that it reflects a trend in other parts of the world. In many countries, states and provinces, the demand curve is rising at a rate that threats to outstrip the possible rate of power development; further, in some regions the full economic exploitation of hydro resources is already within sight and attention is being turned to supplementing these resources by other means.

Certain conclusions can be drawn from these tendencies. In the first place, the demand for the development of hydro resources will continue to be insatiable; there will be no question of a slump in development due to a transfer to other forms of power, for more power will be demanded than can be furnished. Secondly, without contradicting the foregoing statement in the slightest, the energy pattern of the future will be one of correlation between various forms of power. An attitude of "hydro, right or wrong" would be as out-of-date as an old-fashioned imperialism. As we have often urged in these columns, and as the report confirms, the proper co-ordination of various forms of power can produce an economic optimum, and in the co-ordinated power systems of the future, water power will hold an assured and vital place.

World Power Conference Report

THE Annual Report of the World Power Conference for 1955, dated April 1956, which includes an English translation of the Report of the International Commission on Large Dams, was published conveniently in advance of the Fifth World Power Conference held in Vienna last month. Future arrangements that have now been confirmed include a Sectional Meeting at Belgrade from June 5-10, 1957, a Canadian Sectional Meeting from September 7-11, 1958, in Montreal, a Sectional Meeting in Switzerland in 1960, and the Sixth World Power Conference in Australia in 1962. The Report also records the representation of the Conference on the United Nations, UNESCO, UATI, and UNIPEDE. Membership of the World Power Conference has been increased to 47 by the admission of the Saar, Trinidad & Tobago, and Venezuela.

Membership of the International Commission on Large Dams has been increased to 38 by the admission of Ceylon, Spain, and Thailand. The Transactions of the Fifth Congress, held in Paris in 1955, are in course of publication and will occupy four volumes, and the second edition of the Technical Dictionary of Dams is in active preparation. The Sixth International Congress will be held in the United States of America in 1958.

International Association for Hydraulic Research

THE Seventh General Meeting of the International Association for Hydraulic Research is to be held in Lisbon in 1957. The exact dates have not yet been fixed but the period envisaged is about the end of July. The following subjects have been selected for discussion: (a) scale effect in hydraulic research, (b) cavitation in hydraulic structures (such as gates) and dissipation of energy, (c) hydraulics of intakes for water-power stations and of outlets of tunnels and canals, and (d) free subjects.

The Sixth General Meeting took place at the Hague in 1955, and discussed tidal hydraulics, instrumentation, and outlet works, but it has not yet been possible to publish the proceedings. The new Council nominated at the Hague took office at the beginning of this year under the presidency of Monsieur P. Danel.

French Contractors' Record Achievements

AT a reception given on the occasion of the 150th anniversary of the birth of Ferdinand de Lesseps, on January 24, 1956, M. Henri Courbot, President of the Fédération Nationale des Travaux Publics, read an impressive list of the achievements of French contractors at home and abroad. This list includes the following items of hydro-electric interest: The largest reinforced-concrete slab, at Iril Emda dam, covering an area of 17·3 acres; the thinnest dam arch, relatively to the other measurements of the structure (Gage dam); the highest dam arch (Tignes dam); the Pragnères-Cap-de-Long high-head power station, with the most powerful water turbines of their class; the Malgovert and Pragnères dams with their record high-power high-head penstocks; the multiple-arch

Mellègue dam, Tunisia, with a record arch span of 50 m.; the highest dam in Africa: Bin-el-Ouidane; the largest and most powerful run-of-river plants in Western Europe: Ottmarsheim on the Rhine, and Donzère-Mondragon on the Rhone, the latter also including the most up-to-date lock in the world; the most powerful hydro-plant of Western Europe: Génissiat. To these achievements of the last 10 years, France is now adding the Canal d'Alsace, which exceeds the Suez Canal in width and incorporates the Ottmarsheim power station, and one of the highest earthfill dams of the world, Serre Ponçon. And to crown it all: the first of all tidal developments on the Rance estuary.

Tokke Scheme Approved

THE Norwegian Parliament has approved the plans for developing the Tokke water-power resources in Telemark County. The water will supply a power station at Dalen with four generators of 100 MW each. The power scheme is the biggest so far in Norway. The cost is estimated at £25,000,000, and is to be met partly by loans of up to £12,000,000 by a number of county authorities in Eastern Norway, partly by a loan in the International Bank, Washington, and partly by a contribution of £3,000,000 by the Norwegian Government. It is planned to have the first generator working by 1961 and all four by 1963. Minister of Industries Gustav Sjaastad told Parliament that new hydro-electric capacity was now being installed in Norway at the rate of about 350,000 kW per annum. The primary cost of the electricity to be generated by the Tokke/Dalen plant would be about a farthing per kWh.

Cook Strait Survey

THE first phase in the survey of the bottom of Cook Strait to determine the possibility of laying an inter-island electric power cable is almost complete. Information from seismic soundings has been examined by scientists of the geophysics division of the Department of Scientific and Industrial Research. From this it was hoped to have a preliminary picture of the nature of the sea floor.

In the next phase, vessels of the Royal New Zealand Navy are making close surveys in the vicinity of the probable landing points for the proposed cable. These points would most likely be near Cape Terawhiti in the North Island and Tory Channel in the South Island. Then will come a hydrographic survey of the strait bed between these two areas, the taking of samples from the sea floor, and the measurement of currents.

Upper Colorado Development

AFTER a protracted period of fierce controversy, this great $756 million multipurpose development, in which the states of Arizona, New Mexico, Utah, Colorado and Wyoming are interested, has been approved by the House of Representatives. A smooth Senate passage is expected, so that construction work could be initiated in the spring of next year. Besides 12 irrigation schemes, the project is to comprise four major dams: Gravity-type Glen Canyon, on the Colorado River in Northern Arizona, 580 ft. high by 1,400 ft. long, with a reservoir of 26 million acre-ft.; gravity-type Flaming Gorge, on the Green River in N.E. Utah, 440 ft. high by 900 ft. long, with 3·9 million acre-ft. of water; earthfill Navajo, on the San Juan River, New Mexico, 335 ft. high by 3,750 ft. long, with a capacity of 1·5 million acre-ft.; and Curecanti, on the Gunnison River, Colorado, for which studies are still in progress. Power-generating installations at Glen Canyon and Flaming Gorge are scheduled for a capacity of 800 and 72 MW respectively.

Combined Hydro and Thermal Programme for Vancouver

A $50,000,000 hydro- and thermal-electric programme which will add more than 450,000 h.p. to the electric supply of the Lower Mainland and Vancouver Island South over the next five to six years has been announced by B.C. Electric. Construction will start this summer on the development of the second, and ultimate, stage of the company's Bridge River generating plant. Four new machines totalling 320,000 h.p. will be added, raising the total capacity from this source to 568,000 h.p. This will require another massive storage dam to impound water for year-round operation of the four new generating units, a second 2¼-mile tunnel through Mission Mountain, and a new power station approximately half-a-mile west of the existing plant. Two of the four machines will be installed and operating by 1959. The third and fourth are scheduled to go on the line in 1960 or 1961, depending on how rapidly the demand for energy builds up. To supplement the hydro capacity during critical water years and at times of unforeseen outage, work is to start this summer on a 130,000 h.p. gas-turbine plant operating on natural gas. It will contain four generating sets and is stated to be the first large-scale plant of its type in Canada. Three of the machines will be operating in 1958 and the fourth a year later.

Noxon Rapids Contract

WASHINGTON Water Power Company has awarded a $21 million contract for the construction of its Noxon Rapids development to the Morrison-Knudsen Company. This 400 MW plant will be built on Clark Fork River about 38 miles north-west of Thompson Falls and about 20 miles upstream of the Cabinet Gorge plant, which was built by Morrison-Knudsen for the Washington Power Company in 1951-2. Noxon Rapids dam will be 250 ft. high from bedrock and 5,700 ft. long at crest. It will have a concrete spillway and intake section requiring 538,000 cu. yards of masonry and an earth embankment on either side requiring a total of 3,300,000 cu. yards of fill. As we recorded in our October 1955 issue, four 137,500 h.p. vertical Francis turbines designed for 152 ft. head are being supplied by Allis-Chalmers Manufacturing Company.

The Unconventional in Modern Dams. Mr. G. S. Sarkaria, the author of this article, which was published in our April 1956 issue, has asked us to correct a mis-statement in the text. He inadvertently referred to the Roosevelt dam as a multiple-dome structure, whereas the dam he had in mind was the Coolidge.

Fig. 1. An aerial view of Sir Adam Beck-Niagara station No. 1. (right) and No. 2 (left) showing the system of canals supplying the stations

The Sir Adam Beck-Niagara G.S. No. 2

This account of Ontario's major hydro-electric development has been specially written for this journal by

RICHARD L. HEARN, B.A.Sc., D.Eng.,
CHAIRMAN, THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

THE Sir Adam Beck-Niagara Generating Station No. 2 involves eight principal sections, some of which proved to be unique problems in design and construction. These sections included: (1) a control dam on the Niagara River; (2) two separate intakes of the Johnson-Wahlman type on the shore of the Niagara River, some two miles above the Falls; (3) two parallel concrete-lined tunnels about 5½ miles long and 45 ft. in finished diameter; (4) an open canal 200 ft. wide and 2¼ miles long; (5) a forebay with headworks at the top of the gorge above the power house; (6) sixteen concrete-encased steel penstocks 19 ft. in diameter; (7) a power house located six miles downstream from the Falls and containing the generating units, each consisting of a turbine with a rated capacity of 105,000 h.p., directly connected to an 80,500 kVA generator, and (8) a pumped-storage development.

The reason for taking the water from a point some two miles above the Falls and using it at a location situated six miles below the famous Cataracts was to make the best possible use of the head resulting from the natural fall of the river. At mean levels there is a total fall of 326 ft. in the Niagara River from Lake Erie to Lake Ontario. Of this fall, 225 ft. occurs at the Falls and in the Rapids extending for about a mile above them. A further 90 ft. of fall occurs in that part of the river from the base of the Falls to Queenston,

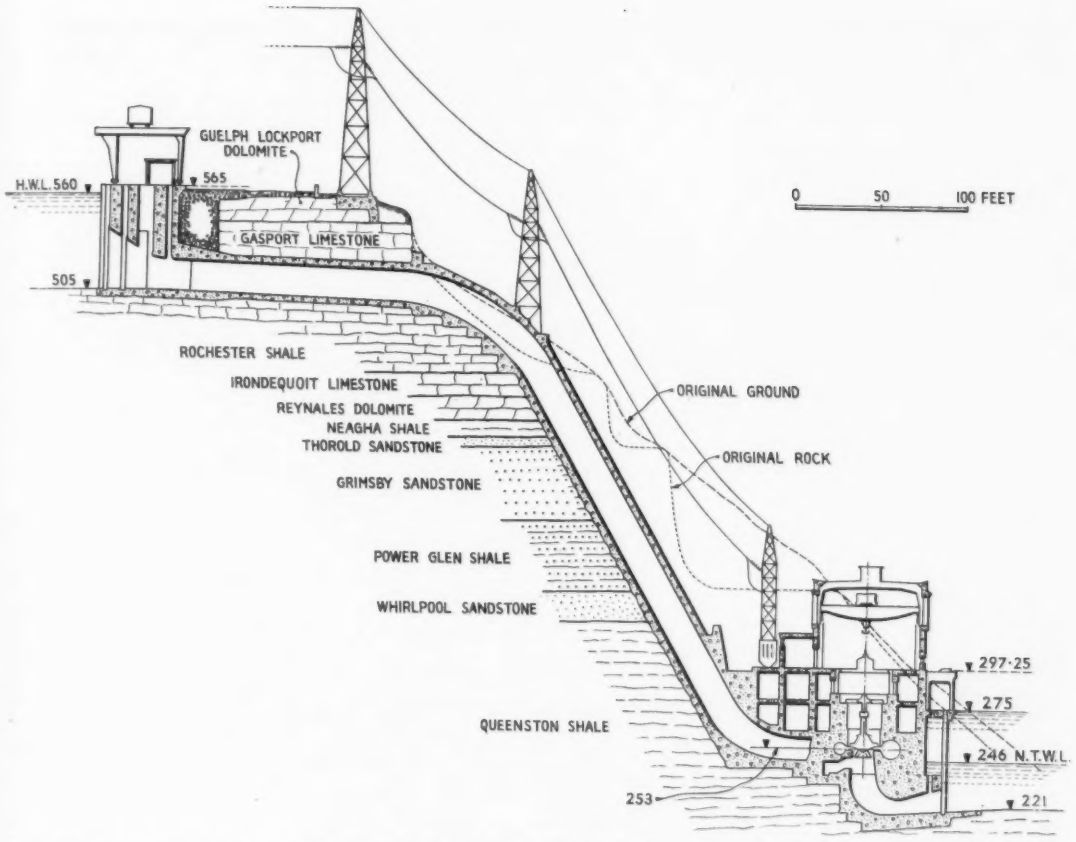


Fig. 2. Section through Sir Adam Beck generating station No. 2, showing the geological structure of the rock

where the power house is situated. Early developments made use only of the drop close to the Falls and neglected entirely the potential in the lower river.

The new development adheres to the principle of utilising as much of the available head as is economic, but takes cognisance of the immense development of the area in more than 30 years since the No. 1 development was built. It was considered inadvisable to impose additional interference on the movement of surface traffic that would result from the construction of one or more open canals. To meet these changed conditions, tunnels were chosen as more suitable.

The Remedial Works

It will be appreciated that the diversion of such large amounts of water from the river for the purpose of power development, thereby reducing the flow over the Falls to the permissible minima named in the Niagara Diversion Treaty of 1950 between Canada and the United States, cannot fail to have a considerable effect on water levels in the river itself and, to a lesser degree, on Lake Erie. The distribution of flow would also be altered and the scenic spectacle adversely affected. This was visualised in drafting the Treaty, and Article II provides for the construction of suitable remedial works.

The works recommended and now nearing completion, consist of excavation and fills near the flanks of the Horseshoe Falls to maintain an unbroken curtain of water over the crest at all times, and a control dam at the outlet of the Chippawa-Grass Island Pool about a mile above the Cataract, and, therefore, above the cascades which extend for rather more than half a mile above the Falls.

The control structure will extend 1,482 ft. into the river from the face of the abutment on the Canadian shore and will have 13 sluices, each with a clear span of 100 ft., separated by piers 14 ft. wide and 91 ft. long. The control dam is being built in sections of two or three gates at a time. Thus, only a small part of the river channel will be obstructed at any time by the cofferdam enclosing the section under construction. Four sluices are now completed and operating.

The purpose of the work at the flanks of the Horseshoe Falls is to assure such a scenic spectacle as will result from a flow per foot in the tourist season approximately equal to that of the American Falls, and will provide an adequate coverage of the crest at other times.

The Intakes

The Niagara River is well known not only for the scenic beauty of the Falls but also for the destruction caused by ice jams. Under certain conditions of temperature and wind, flowing ice on the river has been known to reduce the output of the present plants and, in the case of some of the older ones, to cause a complete shutdown.

The problem in the selection and design of the intake works, therefore, resolved itself into two elements: (a) to extract some 40,000 cu. ft. of water per second from the river with a minimum of head loss without too much interference with natural flow conditions, and (b) to prevent the intrusion of flowing ice into the water-conveying system.

Various studies were made both as to the type of intake as well as their location on the river in relation to the overall plan of development. Following the decision to use tunnels, the choice of the intake site was almost automatic. The chosen location provided the take-off point for the shortest tunnel route to Queenston, keeping it on the Canadian side of the International Boundary, and the maximum obtainable head concentration of the river.

In considering the intake design for the No. 2 plant, it was logical that serious consideration should be given to the adoption of a gathering tube type of intake since it was developed initially to meet the local conditions on the Niagara River. From a review of existing installations and studies carried out by our staff, it was evident that such a structure, located along the shore parallel to the flow lines of the river and with the entry slots located in the vertical outer face, would be desirable hydraulically and it would not detract from the natural beauty of the Niagara Park lands along the river. Located in this manner it permitted unimpeded progress of flowing ice past the structure.

From the results of model tests it was possible to fix the sill elevation at 535·75 ft., in order to keep the lintels well below water surface, the sill and lintel radii at 4 ft., and the slot area at 2,900 sq. ft. In the meantime structural analysis indicated that the piers in the slot should be about 2 ft. 6 in. thick and spaced at 16 ft. 8 in. centres. Tests had indicated that, within limits, pier thickness and spacing had very little effect on performance.

The remaining feature to be determined was the height of the slot to produce uniform draught distribution throughout its length. Tests were continued and a slot height was found which produced, for natural river conditions, approximately equal draught in each 100 ft. section (within one per cent.).

The general dimensions of intake No. 2 are the same as for intake No. 1. However, it was found necessary to vary the vane or pier angle and to introduce a non-uniform tapering slot to achieve comparable performance.

A funnel-shaped excavation in the river bed extending upstream from the structure about 1,000 ft. and outstream 750 ft. was made to intersect a large cross-section of the flow and attract a flow past the structure about 50 per cent. in excess of that to be diverted.

The general layout of the No. 1 intake structure consists of a tapering box section 500 ft. long with the width and height varying from 20 ft. to 45 ft. from the upstream to downstream end. A uniformly tapering slot was formed in the vertical face on the river side which varies in height from 13 ft. 4 in. to 7 ft. 6 in. in the upstream-downstream direction. Concrete piers or guide vanes were set into this slot at an angle of 45 deg. to its longitudinal axis at 16 ft. 8 in. centres.

The overall dimensions of the second tube are essentially the same except that the slot is larger at the upstream end, 17 ft., and smaller at the downstream end, 6 ft. 1 in., has a non-uniform taper, and the vane angles vary. Five upstream vanes are at 55 deg., the next seven at 45 deg. and the remainder at 40 deg. The selection of these three angles rather than a constantly changing vane angle resulted in considerable economy in form costs since prefabricated steel forms were used for this detail. Three such forms were sufficient for the construction of both intakes.

The sills of the slots are approximately 25 ft. below normal river level, the lintels being a minimum of 8 ft. and a maximum of 19 ft. below normal water level.

The structural design of this box-like structure presented many problems. Preliminary stress analysis indicated that it would not be possible to design it as a continuous frame due to the inability of the small cross-sectional area of the vanes to resist the major bending stresses. The vanes are approximately 11 ft. long, 2 ft. 6 in. wide, semicircular shaped at the ends, and are set at an angle to the induced stresses. Therefore continuous horizontal hinges were introduced in the structure above and below the vanes. The structure then resolved itself into a rigid frame with two hinges at the vanes. The vanes act structurally as columns supporting the roof but are not subjected to bending stresses.

Downstream from the gathering-tube slot, a 45 ft. square conduit continues for a distance of about 120 ft. to a control structure. This structure contains a control gate having a clear span of 45 ft., a height of 58 ft., and a weight of 200 tons, and which may be raised or lowered by an electrically operated screw-and-nut arrangement. The gate, which I shall describe in a moment, functions only when it is necessary to isolate a tunnel for inspection or other purposes.

The conduit continues downstream from the gate structure, a distance of about 500 ft., changing from the square to a circular shape, 45 ft. in diameter, to join with the tunnel proper.

Intake No. 1 was placed in service on June 25, 1954, followed by No. 2 on October 20, 1954. It was apparent from the first day of operation that the performance of the tubes hydraulically was identical to that predicted from the model tests. A preliminary field test on the No. 1 intake indicated the energy loss to be within 0·1 ft. of that expected. The surface water flowed past the structure without a trace or indication to the observer of what was taking place beneath the surface.

The Parallel Tunnels

Design and construction of the twin tunnels posed some interesting problems, all of which were again overcome as the result of tests made on models.

The tunnel work consisted of twin bores on 250 ft. centres, each of 51 ft. excavated diameter and a finished diameter of 45 ft. when lined with concrete. Tunnel No. 1, following the outer course around the Niagara River, is 28,560 ft. long, and No. 2, which follows the inner course, is 27,300 ft. long, making a total tunnel length of 10·6 miles. Each tunnel is designed to carry 20,000 cu. ft. of water per second, although tests showed a possible capacity of 23,000 cusecs.

The first decision was in connection with the 48 ft. wide and 58 ft. high tunnel control gates, which are installed immediately downstream from each intake in the 45-ft.-square covered conduits connecting the intakes with the tunnels proper. A transition from the 45-ft.-square conduit to the 45 ft.-diameter tunnel takes place immediately below the gates. Each gate is

Fig. 3. Aerial view showing the main features of the Sir Adam Beck development

(A) Intakes of Sir Adam Beck-Niagara generation station No. 2 and the Horseshoe Falls with American Falls just below; (C) the Whirlpool; (D) one of the project's two work areas; (E) the No. 2 power-house area; (F) the No. 1 power house; (G) switchyard; (H) floral clock; (I) the dotted lines indicating location of the twin 5½-mile tunnels; (B) Canadian 2½-mile open-cut canal; (J) Queenston project camp, one of three during construction; (K) exit portals of tunnels into power canal; (L) reservoir for pumped storage development, and (M) original canal for No. 1 plant.

designed for the following duties: (1) to close under full-load tunnel flow; (2) to open under full upstream head and forebay level downstream, and (3) to open under full upstream head and no tailwater level, or in other words, an empty tunnel. The speed of travel of the gate is set at three-eighths of a foot per minute as the result of other studies where surge and water-hammer effects in the tunnel were investigated.

The alignment of the 45 ft.-diameter tunnels required eleven bends in tunnel No. 1 and ten bends in tunnel No. 2, the majority having a deflection angle of about 30 deg. In view of the size of the tunnels, the number of bends, the scarcity of information on bend losses other than 90 deg., and the great value of minimum head loss, it was decided to make laboratory tests of bend loss to determine the optimum R/D ratio (bend radius to pipe diameter) for a bend, and the actual bend loss coefficient.

The results of these tests are a valuable addition to bend-loss literature, as they indicate the relative effect on bend loss of a good range in R/D ratio and a deflection-angle range of from 30 to 90 deg., using precisely the same pipe in each case.

Actual construction was carried out through five vertical shafts common to both tunnels. Shaft depths were determined by the elevation of the 10 ft.-thick stratum of Irondequoit limestone, selected as the most satisfactory rock layer to use for the tunnel roof.

Construction shafts were located near the mid-point between the main tunnels, and offset to one side of the access drift which connected both tunnels.

With the shaft completed, the permanent tunnel hoisting equipment was installed and put into service. Each shaft was equipped with a counterbalanced cage measuring approximately 9 ft. by 20 ft. with 12 ft. clearance, and designed for a 20 ton working load. The cage ran in the centre of the shaft, leaving a generous space on each side of its shorter dimension. In this space on one side, the two self-dumping skips of approximately 14 cu. yard capacity ran in balance. On the other side of the cage were placed the 48 in. internal-diameter ventilation tubes, the pump discharge lines and water lines.

Hoisting equipment varied between the contractors. A typical arrangement would be a 350 h.p. hoist handling the cage and counterweight and a 450 h.p. hoist operating the balanced skips.

With the shaft completed, tunnel construction was immediately started, applying the method that had been decided upon, that is completing the upper or

heading section before starting the bench section. Temporary skid drill jumbos, handled by a tractor and mounting seven drills, were used to drive the access drift 125 ft. each way from the shaft to intersect the main tunnels.

The two permanent drill jumbos for the upper section of the tunnel were then installed. These jumbos were of three-deck steel construction mounted on flanged wheels riding on 120 lb. rails on 28 ft. gauge. Ample clearance was provided through the jumbo by hinging the inner sides of the two lower platforms of the jumbo so that they could be dropped down, to permit the passage of all mucking equipment. While mucking was in progress, an elevator at the rear of the jumbo lifted all material required for drilling the next round and for supporting the roof rock exposed by previous shot.

Headings were advanced on an alternating basis. The tunnel crew consisted of one drill, one muck, and one support crew per shift. Each completed its cycle of work in one heading and then moved to the opposite one. Since the support steel was placed during the drilling period, the support crew moved with the drill crew. Best progress on the heading totalled 568 ft. in seven, 3-shift days made by the above arrangement of crews alternating in two headings.

Instead of using the conventional wagon drill or horizontal drilling for bench excavation, it was decided to use a jumbo arrangement. This rig was essentially a platform 10 ft. by 50 ft., spanning the tunnel and riding on monorail carriages suspended from the support steel by clamps and turnbuckles. The drill mounting consisted of a 3½ in. pipe attached to the long edge. Movement and position were obtained by using tuggers for both pulling and snubbing. The elevation of the jumbo was determined by referring it to the elevation of the wallplates.

From intake to outlet portal, the tunnels are inverted siphons with the lowest point at shaft No. 5, that nearest the intake. At this shaft a dewatering station has been built in the crosscut between the tunnels so that they can be drained for inspection or repairs. The pumping station contains eight submersible-type four-stage pumps each directly connected to a totally enclosed oil-filled submersible motor of 450 h.p. capacity, supplied with power by marine-type cables from controls at ground level. The station is so designed that even if it is entirely flooded the pumps can be operated. Each pump has a rated capacity of 4,000 g.p.m. against a head of 340 ft. The pumps draw water from a header connected to both tunnels and will be capable of draining either tunnel in less than seven days.

The Open-Cut Canal

As the tunnels approach the outlet portal, they rise at an angle of 30 deg. and converge to discharge their flow into the open canal leading to the forebay. The portals are at the southerly side of St. David's gorge, a prehistoric river channel filled with drift and debris to a great depth. Some 35 years ago this gorge was completely filled with spoil excavated from the canal for the No. 1 plant. The gorge crossing for canal No. 2 is similar to that used for canal No. 1. It was considered inadvisable to cross the gorge with the tunnels, and for this reason, among others, the exit portals are placed to the south so that the water would be taken across by the open-cut canal.

The section of canal crossing the gorge is 2,200 ft. in length, trapezoidal in section, with a bottom width of 94 ft. and side slopes of two horizontal to one vertical. The bed and slopes of the excavation were paved with a layer of crushed rock on which was placed a heavy concrete lining extending several feet above the normal operating water level. Provision is made for drainage into the canal of water in the rockfill, through suitably designed ports in the lining, should the water level be drawn down rapidly.

After passing through a transition from the trapezoidal section, the canal enters a rectangular rock cut extending from the north side of the old gorge to the forebay. This part of the canal is roughly 200 ft. wide with close-drilled sides. It is unlined.

As the new canal approaches the forebay, it is necessary for it to cross the canal serving the No. 1 plant. The plan selected from a variety of proposals to effect a crossing forms an interesting feature of the project. Details of the design were worked out in a model of the adjacent portions of the two canals.

It soon became apparent in the model that the crossing or intersection was actually a merging and redistribution area. A simple solution was found to achieve this distribution efficiently. First the old canal was gradually widened approaching the crossing so that its velocity was efficiently reduced to about that of the new canal when they merged. Next, the centre line of the new canal, downstream from the crossing, was offset 45 ft. By this offset, area was provided for the old canal flow to proceed smoothly into the new canal, and at the same time, a portion of the flow approaching in the new canal was deflected into the downstream leg of the old canal. Offsetting the centre line was the major discovery of the tests. If more flow was to be deflected into the old canal, then the offset would be proportionately increased. The required amount of offset was found to be proportional to the amount of flow interchange.

Careful observations in the model indicated that no appreciable energy loss beyond that of normal channel friction occurred in the cross-over.

Actual experience has shown that by offsetting the centre line of the new canal beyond the cross-over 45 ft. from its upstream alignment, the flow from the old canal is diverted satisfactorily into the new, and part of that coming down the new canal is diverted smoothly into the downstream part of the old canal while the remainder passes into the downstream part of the new canal.

The flow in this downstream part of the new canal is greater, and that in the old canal less, than upstream. This increased flow in the new canal is accommodated by widening the channel to 225 ft. and then gradually to 280 ft. in the next 1,900 ft. of length. At full flow, the velocity is 8 ft. per sec. and the depth 28 ft.

As the canal emerges into the forebay, further widening takes place and the velocity is gradually reduced until at the headworks it is about 3 ft. per sec. Before the headworks are reached, an interconnecting canal between the forebays leads off to the left. This is 100 ft. wide and 700 ft. long.

An interesting feature of the canal and forebay construction was the method used to blast the final plug of rock left until all other work was completed in the new forebay. Throughout the period of construction of the new project, plant No. 1 was maintained in full service. The final plug of rock left in the interconnect-

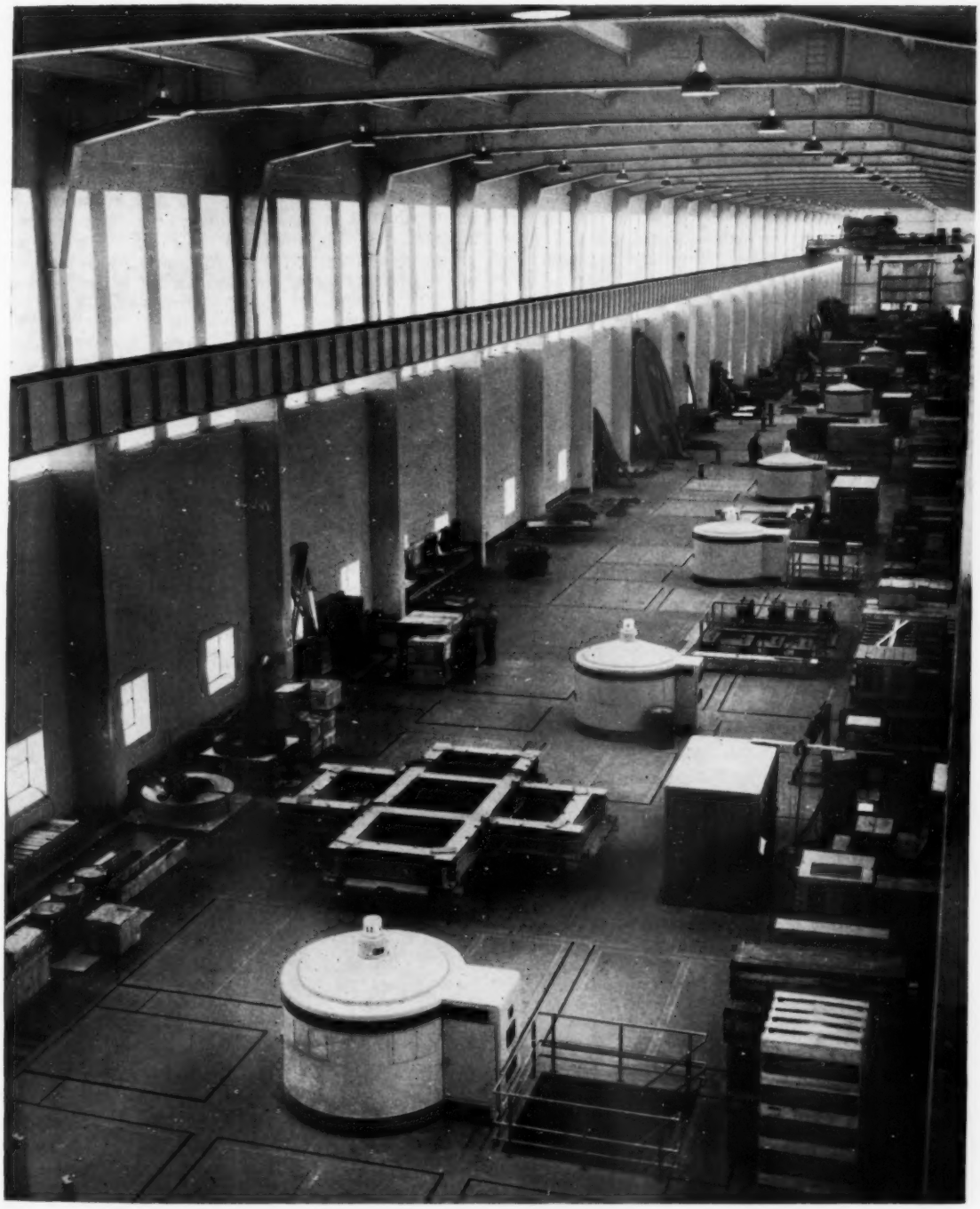


Fig. 4. A view of the north end of Sir Adam Beck Generating Station No. 2 taken during the installation of the twelve 75 MW generating sets

ing canal was blasted out behind a compressed air curtain so as not to damage existing structures.

Because water is non-compressible and would transmit the shock of the blast directly to the headworks of the No. 1 plant, the obvious procedure would have been to close down the generators, drain No. 1 forebay and blast out the obstruction "in the dry." That would have entailed buying power at an estimated cost to Ontario Hydro of some $1,000,000.

An explosives expert from Canadian Industries Limited suggested the introduction of an "air cushion" in the forebay of the No. 1 power house to dissipate the waves of concussion set up by the detonation. If the scheme worked, the entire 25,000 ton rock plug could be shattered with one blast and there would be no need to shut down the station.

Three 3 in. lines, each perforated with 36 holes per foot, were clamped together 9 in. apart. They were closed at one end, and a 6 in. air supply pipe was manifolded to the other ends. The assembly was then lowered to the forebay floor, crossing it on a line parallel to the face of the rock plug.

Vertical blast holes that had been drilled in advance in the rock barrier was then loaded with "Nitrone," an explosive that had been selected because it is not highly sensitive to propagation and comes in water-excluding steel containers.

The air cushion, composed of millions of compressible bubbles, absorbed the concussion so well that the hammering effect transmitted through the water to instruments at the building wall was only 1/70th as intense as it would have been without the air-bubble shock absorber. It was not strong enough to be damaging and was actually far below the danger point. Thus, the plant was kept in service throughout the blasting operation.

Based on the calculations made by the engineers during their experiments, the desired cushion of bubbles was obtained by forcing 90 lb. per sq. in. compressed air into the piping system at a rate of 3,750 cu. ft. per min. The upward rush of the churning air raised the surface of the water about 4 ft. above the normal level.

Forebay and Headworks

After the crossing of the two canals, the water enters the final half-mile of rectangular canal and into the forebay. The shape of the new forebay differs substantially from that for the No. 1 plant. It was found after the construction of the old forebay that the water was eddying at the sides so the shape of the new forebay was designed from model studies.

Tests on the original No. 2 forebay design indicated that the flow would not expand at the rate provided, and serious back eddies occurred. After intensive tests, the original design was modified to provide the maximum expansion that the water would follow, and the walls of the forebay actually traced the streamline for maximum expansion. The interconnecting canal was placed so that all its area would be effective, and it was found that its width could be reduced from that originally planned. The design of the forebay and interconnecting canal eliminated all back eddies and all area was effective.

At the downstream end of the forebay the new headworks, consisting of an 875 ft. long concrete structure, runs the entire width of the forebay. It is here that control of the water entering the penstocks is maintained. There are 32 openings on the upstream side of the headworks, two for each of the 12 penstocks at present installed and for the four future penstocks. Each pair of openings converges into one, inside the structure. In the concrete piers there are three sets of steel-lined gains or checks. The upstream checks house trashracks for screening debris from the water. The next set houses the "stoplog" gates which are used to dewater the headworks for maintenance of the main gates, which are located immediately behind them. These main gates are of steel construction of the fixed-roller type and are operated by electric motor-driven hoists situated in the gatehouse, a modest structure built integral with the headworks. A 25 ton travelling gantry crane runs above the gatehouse and is used to raise and lower the screens and "stoplog" gates.

The Penstocks

Twelve penstocks have been installed, one for each unit, with provision for four more when the balance of the 16 generating units is installed. The penstocks are 19 ft. in diameter and about 500 ft. long, of welded steel construction with the plate thickness varying from $\frac{5}{8}$ in. at the top to $1\frac{1}{4}$ in. at the lower end. Each penstock was built of 68 prefabricated rings and brought to the site by road. They were lowered down the cliff on rails built on the penstock saddles installed in shallow trenches cut in the face of the cliff, on a slope 60 deg. from the horizontal for the greater part of their length. To ensure a perfect joint, each weld was X-rayed and the penstocks were then encased in 2 ft. of concrete to protect them from rapid and extreme temperature variations.

The Power House

The generating station is located on the river bank in the gorge a few hundred feet upstream from the No. 1 power house. In many respects, it exemplifies the progress that has taken place since the earlier station was built. The building itself is an impressive structure of pleasing architectural design, at present 930 ft. long to house 12 generating units. Later it will be extended to 1,150 ft. to accommodate four additional units. It is 63 ft. wide, 50 ft. high, and of rigid-frame steel construction with reinforced-concrete walls and roof. At the downstream end of the power house is the control room which will eventually house the control instruments for both the No. 1 and No. 2 plants as well as for the pumping-generating station.

Before actual construction could begin, a great deal of cliff scaling had to be undertaken. This scaled material was placed along the shoreline in front of the power-house site, forming a cofferdam some 35 ft. wide behind which men could work. This cofferdam was removed by blasting and dredging as the plant was put into operation.

To provide access for truck traffic from the top of the cliff to the power house, a $1\frac{1}{4}$ mile road was built at the upstream end of the power house. This road was constructed by scaling the cliff and casting the material on the shoulder. Access to the power house from the Queenston or downstream end was effected by widening an existing roadbed.

In order to pass in front of the No. 1 power house, an octa-single Bailey bridge for two-lane traffic was built on the cantilever principle over the tailrace of the No. 1 generating station.

Elbow-type draft tubes are used to return the water

to the river after it has given up its power to the Francis-type turbines. These tubes were constructed by using wooden forms built locally and transported to the power-house site by motor float. The forms were set in an excavation at the base of the power house, 42 ft. below the river surface, behind the cofferdam. Concrete was then poured around them and the wooden forms removed when the concrete had finally set. The draft tubes are circular at the upper end to fit the discharge end of the turbine. They then make a right-angle bend transitioning to a rectangular section within the base of the power house, emerging on the river side to discharge the water.

On the concrete slabs forming the draft-tube roofs are set the scrollcases which house the turbines. The steel-plate-lined scrollcases emerge from the back wall at 19 ft. diameter at the base of the penstocks, diminishing in diameter to zero at the end of the scroll where they meet the turbines. This ensures uniform water supply around the speed rings and places equal pressure on all blades of the turbines.

The 12 turbines have a rated capacity of 105,000 horsepower each under a head of 292 ft., and rotate at 150 r.p.m. They are equipped with Woodward actuator-type governors. A single cabinet houses the actuators for two adjacent units. The turbines are spaced 55 ft. centre to centre and are directly connected to vertical-shaft generators.

Each generating is rated at 80,500 kVA, 95 per cent. power factor, three-phase, 60-cycle, 13·8 kV. They are totally enclosed, air-circulation water-cooled, with non-continuous amortisseur windings, and have direct-connected exciters and static voltage regulators. Six are of the conventional type with thrust bearings above the generator, and six of umbrella type with thrust bearings below the rotor. The generators are below the operating floor of the power house, with only the exciters and governor cabinets extending above this level.

The main transformers, which increase the generator voltage from 13,800 to 230,000 V are located on a deck immediately behind the power-house superstructure. One bank of three single-phase 62,000 kVA transformers is provided for each pair of generating units, the output of which is carried to the transformers through a 5,000 A air-blast circuit-breaker and a copper metalclad bus. The high-voltage circuits from the transformers are carried on steel towers and girders, mounted on the penstock envelopes, to the top of the escarpment, and from there across to the switchyard located on the island between the two forebays.

Pumped-Storage Development

The pumping-generating station is designed as an adjunct to the main station, to make use of any surplus energy during night hours to pump water under low head into a reservoir, whence it can be drawn to generate primary energy under high head in daytime periods of high demand.

The pumped-storage scheme consists essentially of a canal to connect into the present canal system, the pumping-generating station, and an artificially created reservoir.

The pumped-storage canal is essentially a reversible-flow channel which conveys water from the main canal during the pumping cycle in which the reservoir is being filled, and discharges it back when storage is being withdrawn to increase load at the main plants.

Fig. 5. One of the two tunnels serving Sir Adam Beck Generating Station No. 2

The canal is approximately 1,450 ft. long and has a normal width of 140 ft., with a flaring section about 650 ft. long to conform with the length of the pump house. The average depth of rock cut was 58 ft. with a maximum at the pump house end of 80 ft. About 20 ft. of overburden covered the rock.

During the pumping cycle, the normal depth of water in the canal will be about 23 ft. and the velocity 8½ ft. per sec. During the generating cycle the depth will be about 26 ft. and the average velocity about 6¼ ft. per sec. with turbines operating at best gate.

The pumped-storage reservoir is an artificial lake about two miles long and one mile wide. It has an area of 750 acres, and, on the basis of 25 ft. of drawdown, will provide usable storage of about 15,500 acre-ft. The reservoir is formed by an embankment, essentially a rockfill mass supporting an impervious clay core for watertightness. This type of embankment was chosen because clay deposits

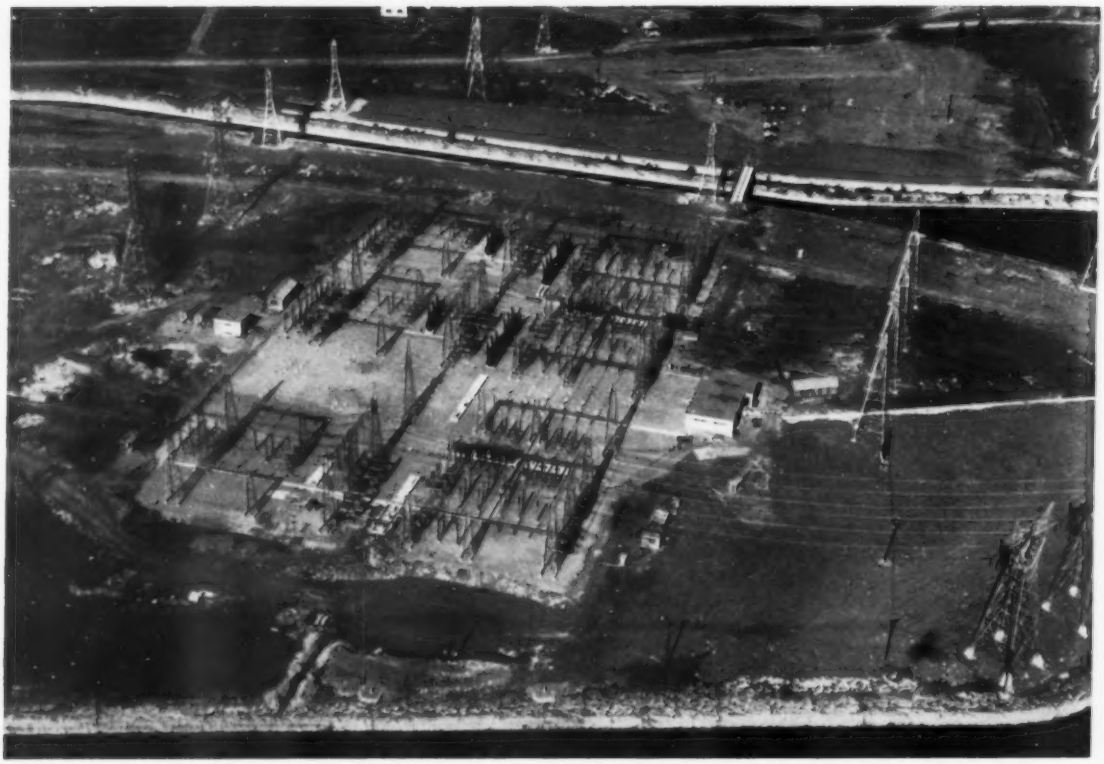


Fig. 6. The 230 kV switchyard located on the island between the forebays of No. 1 and No. 2 plants

were available in the vicinity and the rockfill could be obtained economically from the canal excavation.

The rock in the bottom of the reservoir is generally covered with overburden in variable depth consisting of impervious layers of silt and clay. However, in locations where the overburden has been eroded, or where insufficient overburden or creek beds exist, additional clay will be placed to provide watertightness.

The dyke varies in height from 15 to 65 ft. and has a total length of about 24,300 ft. It involves the placement of 1,300,000 cu. yards of rockfill, 800,000 cu. yards of filter material, and 650,000 cu. yards of compacted clay for the impervious central core.

The equipment to be installed in the pumping-generating station consists of six reversible feathering-blade, Francis-type pump-turbines each direct-connected to a motor-generator. Operating as pumps these units will discharge 4,000-5,000 cusecs under a variable head of from 90 to 60 ft. respectively; for this condition the motor is rated 55,000 h.p. With this equipment it will be possible to fill the reservoir in a period of about 7½ hours.

As turbines, these units are rated at 40,500 h.p. under a head of 80 ft. and the discharge will vary between 5,600-4,100 cusecs with a head range of 80 to 38 ft. (speed 92·3 r.p.m.). If desired, the turbines may be operated to give a constant discharge of about 4,100 cusecs over the full head range.

The power plant consists of a massive concrete headworks structure and the power house itself, which is directly downstream from and integral with the headworks structure. This structure, together with a short concrete gravity section at the west end, forms a dam section between the ends of the enclosing reservoir dykes.

The distance from the face of the headworks to the end of the draft tube is about 125 ft. and the overall length of the power house is 452 ft. An erection bay about 120 ft. long is provided at one end for servicing the units. The units in this plant are 74 ft. centre to centre and are the largest in physical size to date in our system, although this will be exceeded at the St. Lawrence project where the centre-to-centre distance will be 80 ft.

The pumping-generating station is a modified outdoor type and is the first of this type to be constructed by Ontario Hydro. This type of power house was first introduced in the southern part of the United States, but in recent years plants of this type have been constructed in Quebec where climatic conditions are more rigorous than those encountered in the Niagara area.

The pump-turbines to be installed at this plant are of particular interest and are a new development in the field.

The runner is of the diagonal-flow type with eight movable trunnion-supported blades sloping downwards at an angle of 45 deg. from the runner hub. The blade angle is adjusted by a vane-type servomotor located in the runner hub. The hub and inner edges of the blade are finished spherical, permitting unrestricted feathering of the blades and also close clear-

(Continued on page 263)

The 1956 CIGRE Conference

We give a summary of the papers of hydro-electric interest given at the recent sixteenth International Conference on Large Electrical Systems

PART ONE

THE sixteenth International Conference on Large Electrical Systems (known as CIGRE from the French title) met in Paris from May 30 to June 9, and once again attracted a wide representation of leading electrical engineers from all parts of the world. Many of the papers were of especial interest to hydro-electric engineers, and in this first summary of the proceedings we propose to pass through the sections into which the Conference was divided, extracting points from the papers which we believe will be of use to our readers. A second article at a later date will touch on the discussions on these papers and the general proceedings of the Conference itself.

Among the alternator papers the first to be mentioned is that by Mr. D. T. Bath, of the Canadian General Electric Company, dealing with digital electronic systems for deceleration measurements in retardation tests on waterwheel-driven generators. The paper showed that the methods used for loss-testing on large waterwheel-driven alternators by retardation have gradually improved with regard to accuracy, reliability and convenience. The use of digital electronic computing devices in a suitably designed instrument and measuring system, the author stated, can provide an important further step forward in the testing of alternators for the determination of efficiency.

Mr. Bath said that more experience was required in order that this new approach should be properly evaluated; but for the present it appeared to offer much greater convenience in regard both to operations at the test site and to the subsequent computations. In addition, it was suggested that its accuracy and finer definition would seem to be advantageous, not only for the regular retardation tests, but also in tests other than for efficiency. The system seemed to have greater freedom from calibration-type errors than any of the systems previously used. It was readily adaptable to automatic recording of deceleration test data. The apparatus needed was not extensive. Attached to the alternator coupling flange would be a small permanent magnet approximately half an inch in diameter and half an inch long. The pick-up probe would be clamped to the waterwheel coupling flange in such a position that the permanent magnet would pass close to the core of the probe. The impulses from the probe would be taken to a "counter-timer" meter which could be made to be adaptable either to counting incoming pulses over accurately timed intervals, or to timing the intervals between incoming pulses. Counting rates up to 10^6 per second, and time increments as small as 10^{-6} seconds gave an idea of the precision available.

Although it is hoped in our columns to touch at somewhat greater length on the whole question of tidal power, we cannot omit reference to a CIGRE Paper by MM. Gibrat and Kammerlocher of France, which dealt with alternators for the tidal power plant of the Rance estuary. The authors commenced by saying that for a large number of years, in spite of considerable effort on the part of many engineers, the classical vertical-shaft Kaplan turbine adaptable under proper conditions of price and efficiency to simple-effect tidal schemes without pumping has only permitted the designing of schemes of average economic value, comparable, on a basis of investment per kWh, to those which can be achieved at the present time from low-head schemes on suitable rivers. The technique of horizontal-shaft sets, patented in America in 1924, and applied to low-power machines in Germany from 1942, held out some hope that such designs might be applicable in larger sizes, working in both directions.

The authors stated that by 1952 Electricité de France felt satisfied with the progress made in the design of horizontal-shaft sets, and trial units of medium output were ordered for use on suitable sites including Cambeyrac and Argentat. It became apparent that the lunar rhythm of the tides could be completely usefully employed if it were possible to comply with the following conditions of operation:

1. Direct turbine operation, with the sea level lower than the reservoir created by the dam.
2. Reverse turbine operation, with the sea level higher than that of the reservoir.
3. Direct pumping operation, with the machines working as pumps, the alternator becoming a synchronous motor, taking water from the sea to raise it to the level of the reservoir.
4. Reverse pumping operation.
5. Direct sluicing.
6. Inverse sluicing. In this type of operation the sets at rest should permit the passage of large quantities of water in either direction, in order to accelerate the changeover from one of the above functions to another.

If these six functions could be performed, it would be possible (according to the capacity of the network for supplying or receiving power) to guarantee output during peak hours or to concentrate the energy in the winter months into the working hours, or else to produce energy with the sole object of achieving maximum economy of coal fuel in thermal power stations. In addition, the pumping operations could be used for regularising the night load of thermal plants.

The various types of horizontal-shaft turbo-alternators, the authors continued, have shown themselves to be more or less suitable for the conditions set out above. Various designs have been examined, and a test installation on a full scale is being set up by Electricité de France on a disused lock in the port of St. Malo, close to the point where the Rance estuary will ultimately be harnessed.

The sets finally chosen for the Rance tidal-power

station are of the upstream bulb type, with direct drive. There will be about 40 units operating in stages of five or ten. The bulb sets provide the possibilities of relatively easy adaptation to the various functions envisaged, and considerable simplification of civil-engineering work, with maximum ultilisation of the excavations. In addition, there will be a monobloc assembly with two bearings, concentrating the active parts of the turbine and the alternator within a minimum overall dimension and a minimum weight. There would be great ease of maintenance and replacement. The characteristics of the alternators were given in the paper as being of the following order: output 9,000 kW, speed 88·23 r.p.m., with an overspeed of 300 r.p.m. The external diameter of the frame is designed to be approximately 5 m., and the ventilation would be on the closed-circuit principle, operating in air at atmospheric pressure. The authors hoped that the extended study of tidal-power systems on which they had embarked would also be of great service to those concerned with the harnessing of falls with a very low head.

A contribution to the study of the insulation problems that occur in connection with large synchronous machines was given in a paper by MM. Fabre, Lang, Laverlochere, Leroy, Narcy, and Ruelle, all of France. They first stated that in the French network a large number of the hydro-electric generators are of a capacity of lower than 15 MVA, in fact 81 per cent., and it was shown that insulation deterioration causes were numerous and complex. They included thermal deterioration of coil insulation inside the slot, deterioration due to internal ionisation in the parts of the winding subjected to voltage stress, tracking to the frame inside the joint between the slot insulation and the end-turn insulation, and phase-to-phase failure between end-turns caused by the thermal deterioration of Class A insulating materials.

The authors gave very exhaustive details as to the types of test they have applied in order to combat the difficulties due to defective insulation. They included descriptions of the number of special measurement devices developed for this purpose, and they set out in detail the results achieved. They suggested that the very nature of the insulating materials used in this field is such that practice is subject to constant evolution, especially due to advances in the chemistry of plastic materials. In consequence, they felt that there could be no question even now of establishing precise standards or of fixing characteristics to be imposed on insulating materials; but they were of the opinion that experience acquired so far by the methods they outlined in the paper would facilitate a more rapid knowledge of the qualities of new insulating materials.

In regard to transformers the International Study Committee of CIGRE dealing with this field decided that there were eight subjects to which active consideration should be given. These were:—

On-load tap-changing gear.
Transformer noise.
Chopped-wave impulse testing, with particular reference to fault detection.
Special features of large power transformers.
Automatic control of on-load tap-changing gear.
Thermal aging and the thermal evaluation of insulating materials.
Ionisation and insulation maintenance.
Loss ratio and capitalisation.

The question of on-load tap-changing gear was further discussed in a paper presented on behalf of the Study Committee by Mr. E. C. Rippon of Great Britain. While it may be said that the main features of the transformers themselves have become largely standardised along one or two lines of progress, there is still much room for research and experimentation in regard to tap changers. In particular, many problems arise when the performance of tap-changing equipment has to be specified. The paper presented by Mr. Rippon set forth the various discussions which took place on these subjects. He said that it was generally accepted after some discussion that a tap changer could be treated as an individual piece of apparatus to establish its rating. A factor designated by the symbol K was evolved, to evaluate the relationship between the rated switching current and the rated continuous current. The rated switching current was expected always to exceed the rated continuous current by a factor of K, and some of the experts on the Study Committee considered that two values of K might usefully be taken into account when evolving specifications. The first, say K_1, would derive the rated switching current which the diverter switch assembly could handle without abnormal arcing. A second and higher value, K_2, would derive the current which the diverter switch could handle without failure of the arc to quench, or subsequent failure of the equipment to operate, but permitting excessive loss of contact material during the operation.

The paper went on to discuss type tests relating to contact heating and switching duty which could establish contact ratings. Other tests were outlined in the paper for mechanical strength and endurance, while there were also proposed dielectric type tests.

A considerable number of papers related to the subject which has occupied so much time at CIGRE in recent years—the impulse testing of transformer windings. From two engineers at the Ateliers de Secheron (Switzerland), MM. Froidevaux and Rossier, there came a paper on the maintenance of the wave shape during impulse testing, and its importance.

They showed that the shortening of the time to half peak value by change in wave shape does not reduce the internal stresses in the winding to an appreciable extent; on the other hand any lengthening of the wave front produces a considerable reduction of the stresses across some sections of the windings. Dr. Waldvogel and M. Rouxel (Switzerland and France) discussed the predetermination by calculation of the electric stresses in a winding subjected to a surge voltage, and they stated that by subdividing the winding into elementary coils, and considering the capacitances between coils and to earth and the self and mutual inductances, they could evolve a clear and precise theory of the transient phenomena in a winding subjected to a surge.

Mr. L. L. Preston, of Ferranti Limited, Great Britain, also returned to the subject of impulse testing, and dealt with the characteristics of rod gaps before entering on a description of the requirements necessary for fault detection during impulse testing. He stated that chopped-wave testing was satisfactory but that the method needed apparatus and techniques of a higher standard than that required for full-wave testing.

Chopped waves were also the subject of a lengthy paper by MM. Langlois-Berthelot, Monnet, Derippe and Favié of France. They gave details of a large

number of tests and they indicated that the utilisation of a slow front wave was possible when carrying out chopped-wave testing. The front duration must, on one hand be at least six times that of the full-wave test, and on the other hand it must be sufficient for the line current not to present appreciable capacitative or high-frequency components. The authors said that the usual detection and fault location methods could be utilised, subject to certain improvements.

In the switchgear section perhaps the most interesting papers were those by Messrs. Skillen and McKeough, of the Canadian Westinghouse Company, on a new circuit breaker designed to meet Canadian requirements, and the paper on the most recent progress in the field of air-blast circuit breakers, by H. Thommen, of Brown Boveri, Switzerland.

Messrs. Skillan and McKeough built up a fascinating picture of the Canadian engineers designing a type of circuit breaker which would satisfy the Canadian Supply Authorities, and which could be made at a price which would compete with rival products both from North American sources and from Europe. They decided that the following criteria should be taken into account. First, the integrity of the grounded steel tank should be preserved. Secondly, porcelain parts should not be used in any member where that member could be subjected to tensile stresses. Next, bushing-type current transformers and potential taps were regarded as essential. The dielectric should be non-inflammable and cheap, and the whole breaker should be mechanically simple, easy to maintain, easy to install, economical of space, and the required foundation should be simple and inexpensive. In addition, the design should be balanced to Canadian economics. This formidable list of desiderata resulted in the evolution of a design in which a grounded steel tank was used with compressed-air dielectric. Most interesting details were given in the paper, which is too lengthy to summarise usefully.

Mr. Thommen described the high-speed air-blast circuit breakers made by the Company with which he is associated, and which have been successfully put into service for voltages up to 400 kV with rupturing capacities of up to 20,000 MVA. These breakers, the construction of which, at first glance, appears to be of light porcelain, are so arranged that each separate rupturing chamber can be fully tested out. The author stated that the deduction of the total rupturing capacity from the results obtained on one chamber is fully justified by lengthy experience acquired with switches in service. The different models are made up of the same fundamental parts, allowing for mass production and for many other benefits.

Other papers in the switchgear section of the 1956 CIGRE Conference related to a considerable extent to the evaluation of system constants, particularly in regard to restriking voltage conditions. It appears, nowadays, that most supply engineers are devoting considerable effort to providing up-to-date information of this subject, so enabling them to be much more precise than hitherto when specifying circuit breakers for use under particular operating conditions.

There was, however, one paper of special interest to those supply authorities who have reason to consider the prime factor of economics above all other considerations. A paper by MM. Cabanes and Dietsch, of Electricité de France, described a method of connecting up a high-voltage substation with a single circuit breaker for each busbar, this breaker being connected in parallel with the busbar. The various protective-gear circuits, which can be set up to eliminate every type of fault by the use of this breaker were described in detail. The method appears to have a very considerable economic promise.

It is hoped that in our next issue a further commentary on the papers at the 1956 CIGRE Conference will be published.

(To be continued)

Atlas Copco Acquires Arpic Interest

Atlas Copco has expanded its production capacity by acquiring the controlling interest in the Belgian firm of compressor manufacturers, Arpic Engineering S.A. Arpic has companies in Great Britain, Mexico and Bolivia, and in 1952 completed one of Europe's most modern portable-compressor factories near Antwerp. They also have a plant in Scotland and a network of agents and distributors throughout the world.

The Arpic range of compressors comprises seven sizes having free-air deliveries from 105 to 550 cu. ft. per min. All are of the two-stage type and are powered by Perkins diesel engines except the largest sizes, which are equipped with A.E.C. or Dorman units. The addition of this range to the Atlas series means that Atlas Copco can now supply portable compressors with capacities ranging from 36 to 550 cu. ft. per min.

Associazione Nazionale Imprese Produttrice e Distributrice di Energia Elettrica (ANIDEL). We have re-received the special issue of "L'Energia Elettrica" devoted to the activities of the ANIDEL association in 1954, a year which marked the tenth anniversary of its reconstitution. In addition to the general reports and statistics submitted to the general meeting held on June 22, 1955, this issue contains 20 plates and folders in colours which present an exhaustive picture of hydro-electric development in Italy. The reports of the Technological Section and of its Research Committees are also given; among these, the report of No. 9 Committee illustrates the close co-operation between the Association and the laboratories of the Italian Technical Universities.

Overhead Line Equipment. A comprehensive 112 page catalogue has been issued by Pirelli-General Cable Works Ltd., Southampton, giving details of equipment for overhead lines. It is divided into the following sections: Transmission Lines on Poles, up to 33 kV; Transmission Lines on Towers, 33-220 kV; Special Structures, including radio, floodlight and other towers; Aerial Cable Supports; and Ancillary Equipment.

A. Reyrolle & Co. Ltd. have forwarded a pamphlet describing their Class J switchgear, which consists of oil-break ironclad units for standard voltages up to 11 kV and for a normal current rating of 400 A. Units can be supplied in single-switch, double-switch, fuse-switch, and ring-main forms, all except the last-named being available either in extensible or non-extensible form. A second pamphlet relates to their Type F multi-contact high-speed tripping relay.

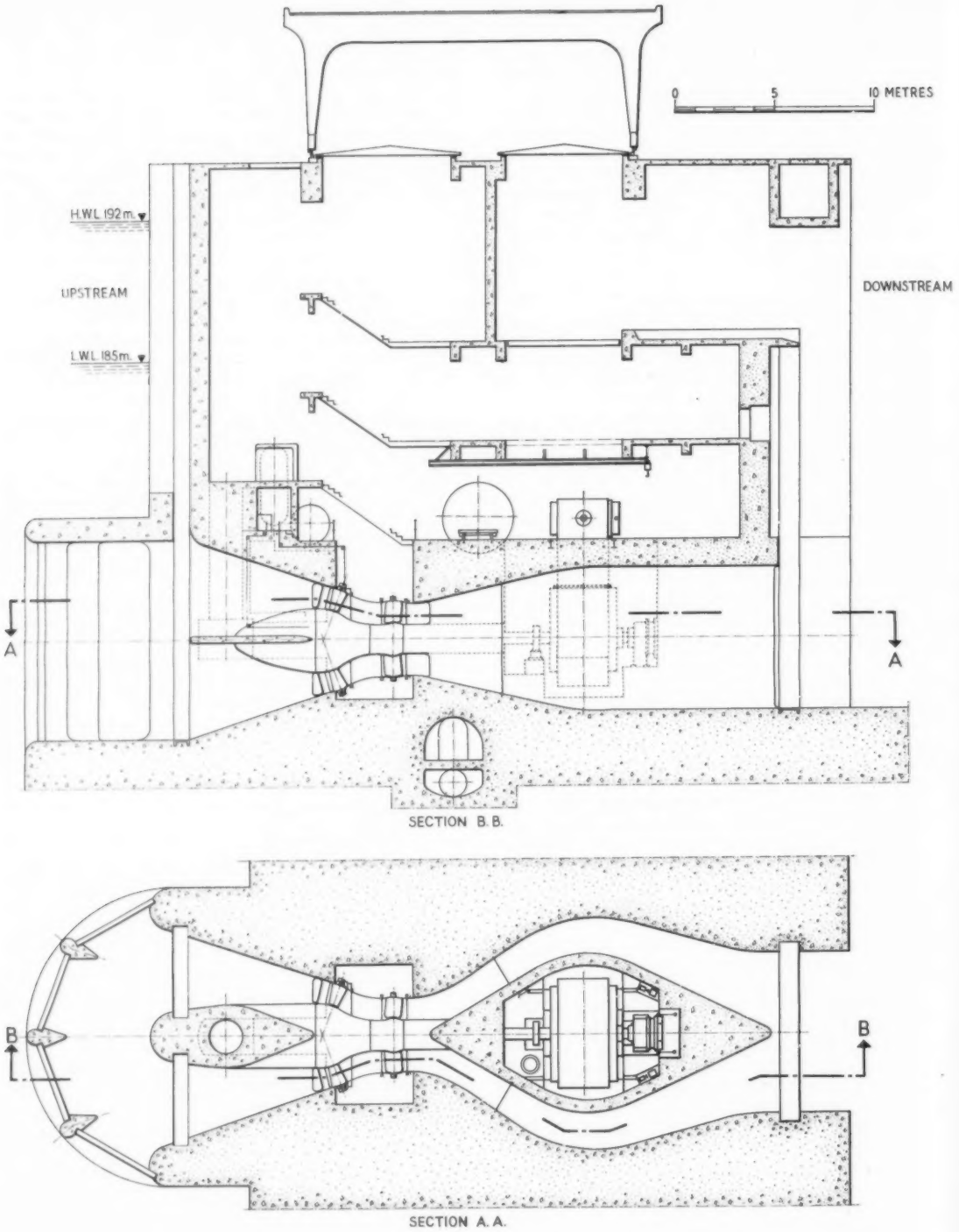


Fig. 7. Argentat plant: sectional views of a tubular turbine with generator in shaft

TIDAL POWER

Tidal Power

Dr.-Ing. Gerhard Wickert, Dortmund, Dozent at the Technical University, Karlsruhe, outlines the fundamentals of tidal power, and reviews current trends in the design of turbines and civil-engineering structures suitable for this service

PART TWO

IN tidal power houses the problem of foundations is of outstanding importance, and the procedure to be followed must be determined in each instance individually, taking fully into account the conditions obtaining on site. In the case, for example, of a power house set up at a spot subject to storms, either off the coast or in a bay, the structures must be calculated and designed to withstand these gigantic forces of nature, that is to say all foundations and supporting structures must be substantially overdimensioned so as to withstand catastrophic conditions and prevent major outages. As a rule, a tidal power house equipped with tubular turbines can be provided with flatter foundations than is the case with vertical-shaft turbines, the draft tubes of which extend to some depth. Drawn in perspective, a tidal plant operated by two-wheel turbine-pumps would have the characteristic features shown in Fig. 6. From the hydraulic aspect, the turbine with horizontal inlet and horizontal outlet is a very favourable solution. In accordance with the water level, the power flow moves from sea to basin or vice versa. The walls of the power house on the basin side must therefore be calculated and reinforced so as to cope with the highest water level. Access to the generators, each enclosed in a bulb-shaped casing, is ensured by a service passage running along the whole length of the power house, and also housing the ventilation ducts and electric cables. Compared with hydro-electric plants of traditional design, the inner hall of a tidal power house gives an impression of emptiness, all the machinery being hidden underneath the floor. Actually, the only visible part of the equipment is the travelling crane provided for handling heavy parts of the generating sets.

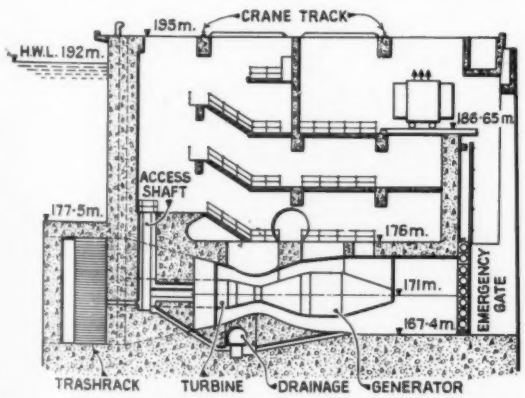


Fig. 8. Argentat plant: longitudinal section of tubular turbine with submerged generator

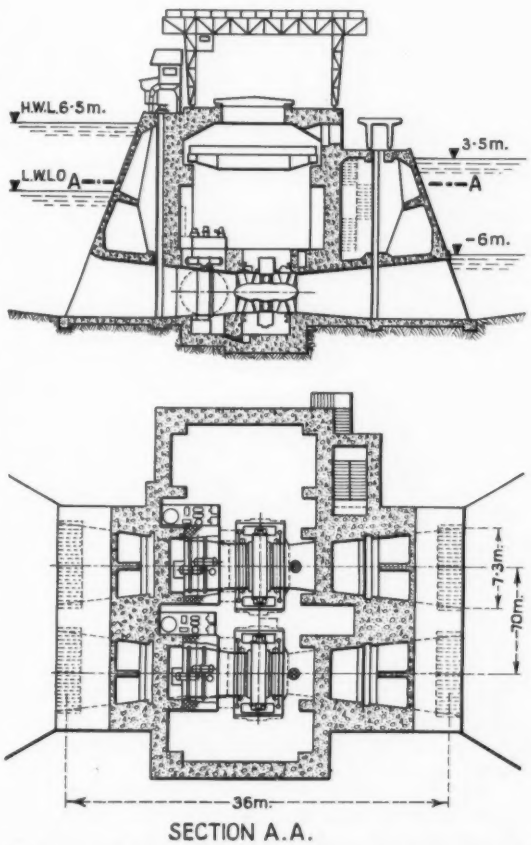
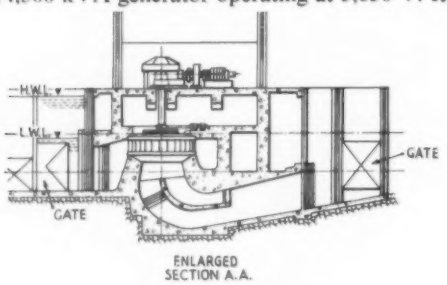


Fig. 9. Tidal power house with tubular turbines of the single-runner double-guide-vane type

Considered from the viewpoint of tidal development, the Argentat power station on the Dordogne River presents features of uncommon significance. It is, indeed, the first large-scale instance of an inland hydro-electric plant displaying a battery of generating units designed to satisfy operating conditions similar to those to be encountered in tidal plants. The tubular turbines provided for Argentat have a discharge capacity of 100 cu. m. per sec. As to generators, two different types are contemplated, the units being mounted either in separate pits, as shown in Fig. 7, or enclosed

in bulb-shaped steel casings, as seen in Fig. 8. In the former, now on order from the Alsthom-Charmilles concern, an inspection shaft (see Fig. 7) gives access to the turbines, which have Kaplan runners. The draft tube terminates in a bifurcation (Fig. 8), and the generator in the pit is mounted on the extended shaft of the turbine. The bearing of the generating unit is located in the downstream wall of the pit, and the governor is mounted on a platform above the turbine. Each unit is designed to operate in both directions as a generating or a pumping set, the turbine output being 19,500 h.p. at a head of 16·5 m., and, acting as a pump, 59 cu. m. per sec. with a lift of 10 m. Pit mounting enables an easily accessible generator to be used, of normal design and with an adequate PD^2.

In the enclosed type (Fig. 8), the turbine drives the generator by means of gearing. The streamlined casing is fully surrounded by the flow, and encloses a 14,500 kVA generator operating at 5,650 V. It will be



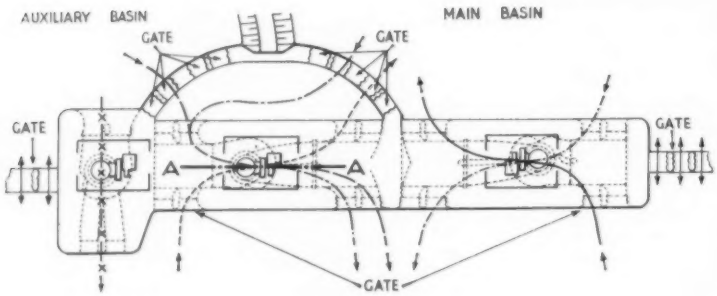


Fig. 10 (left). Tidal power house with elbow draft tubes

Fig. 11 (below). Double-admission tidal power house with revolving draft-tube elbow

left to actual practice to show which of these two types of generating units will be better suited to tidal power plants.

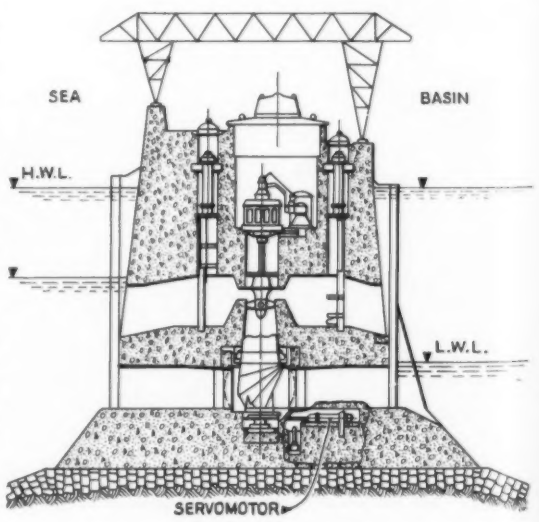
The Voith type of tubular turbine with two sets of guide vanes and a single runner would enable the lay-out of the power house to be simplified to some extent; the runner being encircled by the generator, the width from the intake inlet to the discharge outlet could be reduced (Fig. 9).

Tidal plants equipped with vertical turbines and operating with one-way power flow only do not substantially differ from the usual type of inland low-head run-of-river installations, but if two-way working is to be made possible the turbine inlets and the draft tubes must be gated to suit the direction of the flow (Fig. 10). Another solution would consist in providing a revolving elbow-type draft tube which would not only create favourable flow conditions in either direction but also take the place of two gate-valves (Fig. 11). Water being available in abundance, it is quite feasible to divert part of it through special channels running either underneath (Fig. 12) or above the turbines. This would create a dynamic suction head which would enable turbines of the usual type to operate as ejector turbines at an appropriate increase in output.

Dam Construction

If the dam is set up as a rockfill or earthfill structure, the following procedure appears to be practicable. The fill material is dumped either from chutes or by means of cableways; this results in gradually narrowing the cross-section of the flow, and increases the velocity of the water flowing over the dam body into or out of the bay (Fig. 13). The grading of the fill material must be adapted to this increasing velocity of the flow, which varies in accordance with the thickness of the overflowing layer. Another possible solution would consist of sinking prefabricated structural parts which would be floated to site on rafts or boats (Fig. 14). A curtain of sheet-piling, topped by packed rockfill, would protect the dam from undermining on the sea side.

In the case of a two-basin system, the dam separating the two basins could be designed as a concrete structure consisting of arches spanned between piers on both faces, thus forming hollow cells into which water would be admitted to a level corresponding at any time to the highest level of the water outside the dam, so as to improve the stability of the structure (Fig. 17). Openings in the walls would permit a balance between the outer and inner water pressures to be established in accordance with the height of the



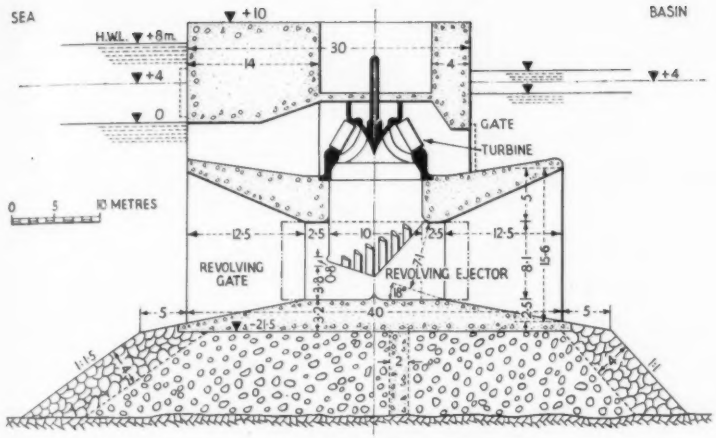


Fig. 12 (left). Cross section of a tidal power unit with ejector

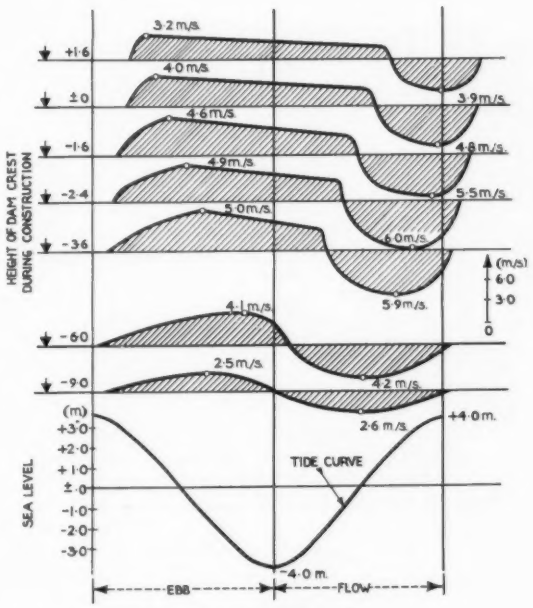


Fig. 13 (below). Flow velocity for a rockfill dam under construction plotted as a function of overflow depth

ebb or flood tide at any given moment. The walls connecting the piers are arched both vertically and horizontally, and their shape has been determined on economic grounds. They can be prefabricated, either on site or any other convenient spot, and then, once the sea bed has been prepared, floated to their erection point where they are set upright and lowered into position. Inside each cell there is an inspection and service gallery from which high-pressure grouting can be effected to improve imperviousness and avoid undermining. In addition to grouting, full bags of cement, and blocks of rock are sunk around the outer toes of the structure to reduce the danger of piping.

On the other hand, the sea dam (Fig. 16), submitted, as it is, to much greater strains, requires a much stronger construction. Hollow prefabricated concrete blocks constitute satisfactory structural members, which can be floated to erection site, sunk and assembled in two rows of piers braced by struts. The bottom blocks are fitted at their outside toes with hinged strips or grating which, upon the block being in position, are folded back to the sea-bed. The purpose of these strips, under which the water remains undisturbed by the ebb and flood motion of the tide, is to minimise the effect of water on the toe of the dam. Once the two rows of piers are completed, the intermediate space is drained by pumping to enable any further necessary work to be done comfortably in the dry.

Silting

The incoming tidal wave is laden with drift detritus which settles in the basin as the water calms down. In the opposite working cycle, the water may well flow out of the basin but never reaches such a velocity as to enable it to return the deposited materials to the sea. The unavoidable result is an uninterrupted silting of the basin which only dredging can remedy. Conditions may be even much worse in estuary tidal plants, especially in the case of heavily drifting rivers, their eroded material settling in the basin on the top of the sea detritus. The Kiel Canal, especially at its junction with the Elbe estuary, is a typical instance of these awkward conditions, for no less than 20 million cu. m. of solid materials, that is to say the equivalent of a dredger output of 70 million cu. m. of wet material, must be disposed of every year to maintain an adequate depth in the navigation channel. Worse still,

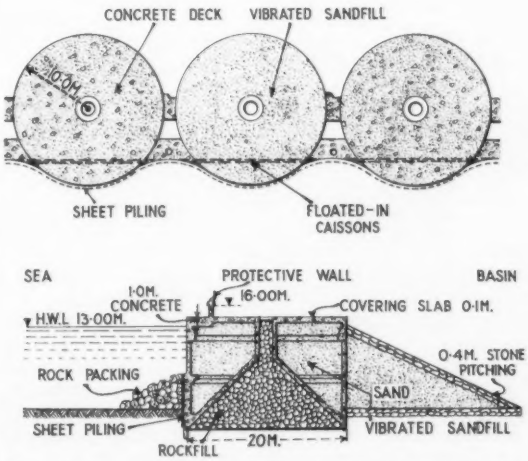
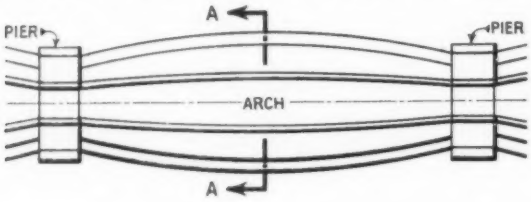


Fig. 14. Construction for a prefabricated dam using floated-in caissons

the discharge of mud and sand at the sea lock at Brunsbüttelkog is such that, were it not for practically non-stop dredging, the bed of the outer harbour would rise at the rate of 0·8 m. a month.

Navigation

This leads us to the problem of navigation in connection with tidal plants. The power installations set up at the mouth of a river, especially the dams of the basins, close the waterway to navigation. Sealocks of appropriate length and width, preferably equipped with horizontal rolling gates, must be provided at each dam. Since the crowns of the lock operate alternately as downstream and upstream structures, the gates must be designed to cope with the pressure of the water on either side, while at the same time, controlling the filling or emptying of the lock chamber. It goes without saying that, when determining the mode of operation of a single-cycle or double-cycle tidal plant, not only must due consideration be given to all economic and technical aspects of energy production, but navigation requirements must also be taken into account. A defective operating cycle may give rise to wide fluctuations of level within a short space of time, thus producing in the basin and in the downstream stretch of the estuary very difficult, if not altogether impossible, conditions for navigation.



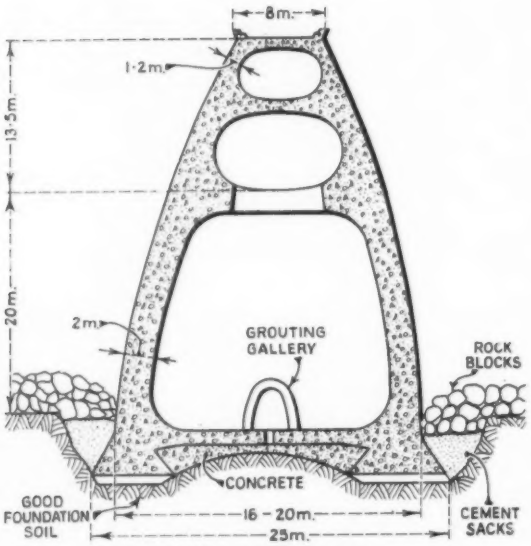


Fig. 15. Details of multi-cell dam between the basins of a two-basin tidal plant

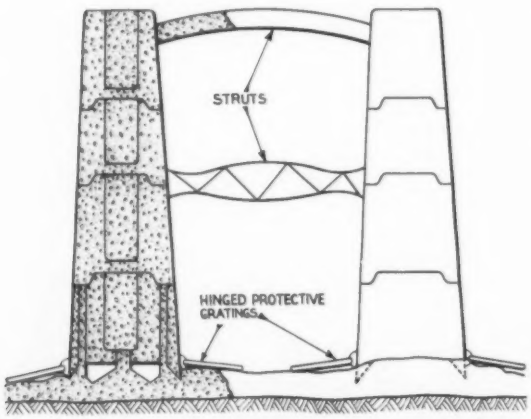


Fig. 16. Sea dam for tidal plant, constructed of prefabricated blocks

Projects Under Consideration

The two dominating factors which intervene in tidal power schemes are the tide range and the area of the power basin. It is therefore obvious that favourable sites are ever so much scarcer than is the case for normal river developments, and tidal power plants can prove a paying proposition only in coastal regions which, on the one hand, owing to suitable topographical conditions, lend themselves particularly well to the setting up of vast power basins, and, on the other, are favoured by tide ranges which enable the turbines to operate under an economically advantageous head. The sketch maps of Fig. 17, all drawn to the same scale, refer to seven of the most advanced projects, and give fair examples of sites favourable to the setting up of tidal plants. Prominence must be given to the Argentine plant, with a generating equipment of 376 units, projected in the Bay of San José, which is expected to deal with a tidal discharge varying between 90,000 and 150,000 cu. m. per sec., according to the tide range, and to reach a yearly production of 10,000 million kWh. The production of the French Chausey scheme, if carried into effect, is assessed at 15,000 million kWh, that is to say more than a half of the aggregate production of all hydro-electric developments now in operation in France. The production figures of British projects, as far as contemplated, may appear unpretentious when compared with those of the above-mentioned schemes, but are still quite impressive. The Severn Barrage scheme, perhaps nearest to the construction stage, is to produce 2,400 million kWh per annum, and the corresponding figures for Solway Firth, Morecambe Bay and Carmarthen Bay are 8,800, 5,100 and 3,000 million kWh respectively.

Conclusion

In view of the ever growing energy requirements, the urgency of a thorough investigation of the potentialities of practicable tidal power schemes is hardly to be questioned. Mechanical and electric engineering on the one hand, civil engineering on the other, have already made such useful contributions to the advance of these schemes that the first tidal plants are expected to enter the construction stage in the very near future. Turbine-pump units have reached the required high degree of reliability and working efficiency, an economical solution of the problem of the output fluctuations inherent in tidal power generation is at hand, and, with the means available today to con-

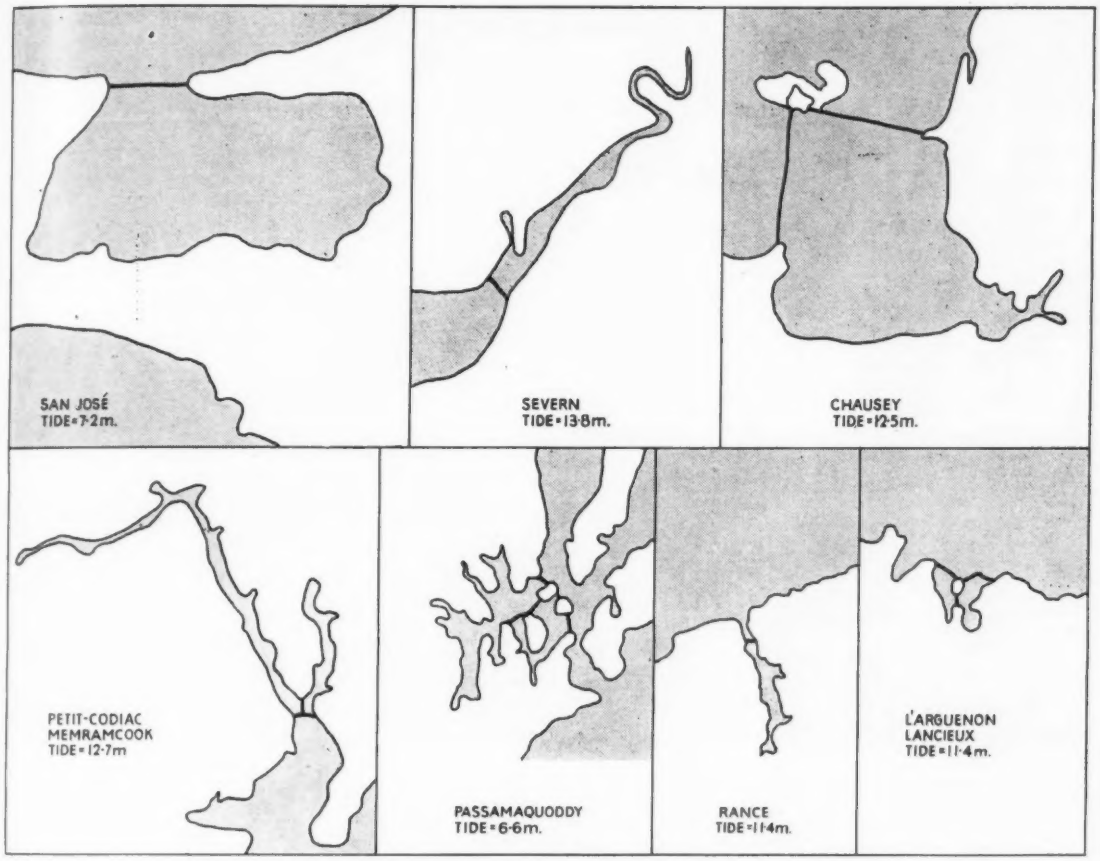


Fig. 17. Site maps drawn to the same scale of projected tidal schemes

tractors, there is hardly any difficulty of a civil-engineering nature which cannot be overcome: all these factors combine to lead to the conclusion that, from both the engineering and the economic aspects, tidal power plants are today a perfectly practicable proposition. Besides, the progress achieved in the construction and equipment of run-of-river power developments can be applied practically in full to tidal schemes, and with the support of unceasing theoretical and practical research, there can be no doubt whatsoever that new methods will come to fruition, bringing about further improvements which will facilitate the setting up of the first tidal plants, and greatly foster the promoting of future ventures.

From page 254

ance tolerances. Likewise, the outer edges of the blades and the throat ring wall are spherical. Because of the close clearances between the hub, the blade edges and the throat ring, the blades in the closed position form a reasonably watertight closure and the conventional wicket gates and their operating mechanism have been eliminated. When the machine is shut down additional thrust may be introduced on the top of the runner hub by closing the headcover drain valve, which produces a deflection and reduces the clearance between ends of the blades and the throat ring. This reduces blade gap leakage to a minimum. The steel-plate casing is set well above the centre of the blades to ensure axial flow past the blades.

The unit, when acting as a pump, is started with the blades in the closed position and brought up to speed without the necessity of depressing the water level in the draft tube. This requires very little effort other than the inertia of the runner and motor, and starting will consequently be across-the-line with the expected inrush current about 250 per cent. of running current. When synchronous speed has been attained, the blades will be gradually opened and pumping begins.

The units will be operated at 13·8 kV with transformation directly to 230 kV and connected to the system at the present switchyard. When operating in the reverse direction, the main leads and such other controls and protective circuits as are necessary will be reversed.

Her Royal Highness the Duchess of Kent graciously consented to open the Sir Adam Beck-Niagara Generating Station No. 2 on August 30, 1954, and one year later the first stage incorporating 12 units was in full operation. Because of the unusually high rate of load growth being experienced on the Commission's system, it was announced in January of this year that work would commence immediately on the balance of the units. Thus, by 1958 the entire project, including the pumping-generating station, will be completed at a total approved cost of $343,742,000.

Fig. 1. The spillway of Storfinnforsen dam during construction

The New Stations of the Krångede Power Company

Further to our recent series on the developments in the Ångerman catchment sponsored by the Swedish State Power Board*, we now give an account of the work of the Krångede Power Company in this area and describe the recently completed Storfinnforsen station and the Ramsele station now under construction

PART ONE

FOR many years Swedish power policy has placed ever-increasing emphasis on the bulk transmission of power from the mountainous north to the industrial and commercial south—a policy which has found its most recent expression in the construction of the 380 kV transmission line, already described in these pages,† from Harsprånget to southern Sweden. It is only natural that an enterprise on the scale of the then highest-voltage transmission line in the world should have been sponsored by the State, but the inception of this policy is to be found in co-operative action amongst private interests. Indeed, one of the signs of economic and political health in Sweden is the amicable coexistence and co-operation between the State Power Board and private power companies.

The Krångede Power Company, of Stockholm, is an outstanding example of a co-operative organisation conducted by industrial and municipal interests for the bulk generation of power for their own use. This

* "Developments in the Angerman Catchment." WATER POWER, June, July and August 1955, pp. 202, 247 and 292.
† "Harspranget." WATER POWER, January 1952, p.4.

company can trace its origin as far back as 1916, when five large ironworks in central Sweden bought the Krångede Falls, one of the largest in Sweden, on the Indals river, about 350 km. from the prospective load centre. The Indals catchment lies in the Province of Jämtland in northern Sweden immediately south of the Ångerman catchment described in our previous series of articles. These ironworks were soon joined by the Berslagen Co-operative Power Company, a concern operating in central Sweden, to form the Krångede Power Company, and later two of the ironworks sold their shares respectively to the Koranäs Sawmills Company, near Gävle, and to the City of Stockholm.

The first station to be built by the company was at Krångede, and initially—in 1936—contained two 30 MW sets but now has a capacity of 210 MW. The first 220 kV transmission line to be constructed in Sweden led from Krångede to Horndal in Bergslagen, a distance of 340 km. Later a second station was built 5 km. farther down the Indals at Cammelänge, having a capacity of 60 MW, and a third plant, of 40 MW capacity, was erected on the same river at Mersil.

The Fax River

With these installations the development of the Indals reached its economic limit, and the continually increasing demand for power made it necessary to look elsewhere for sources of supply. With this object in view the Krångede Power Company in 1940 pur-

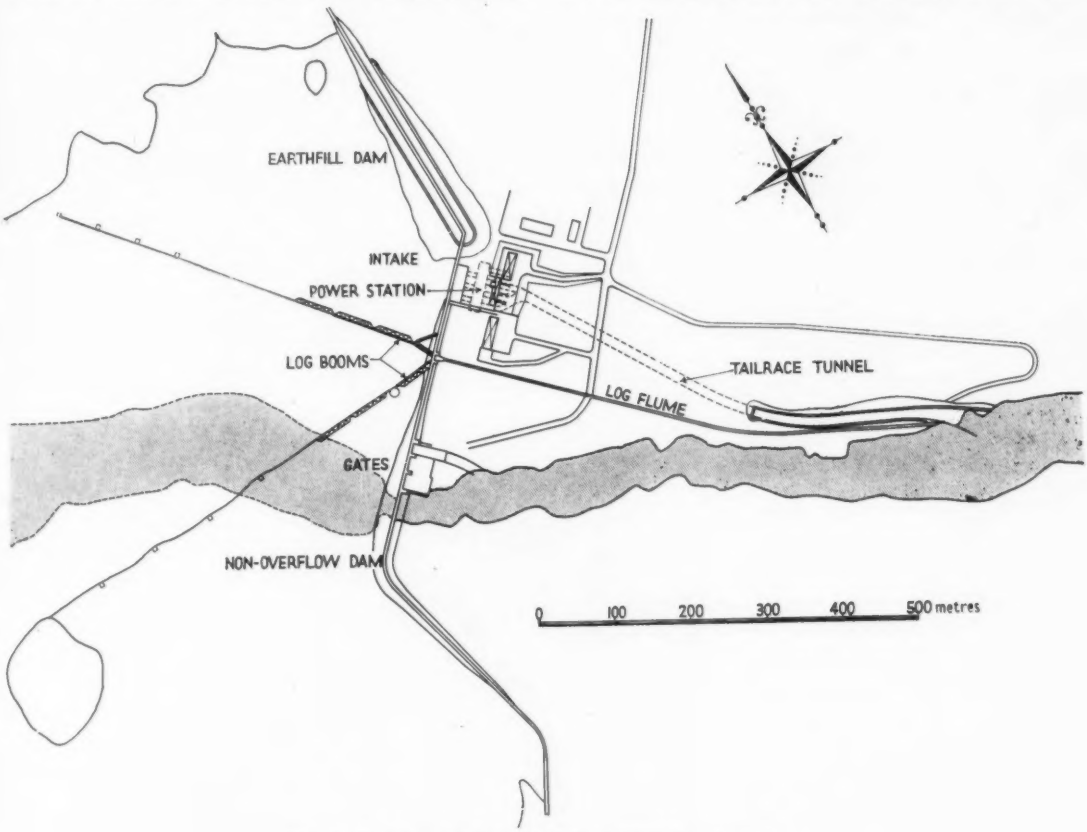


Fig. 2. Site plan of the Storfinnforsen development

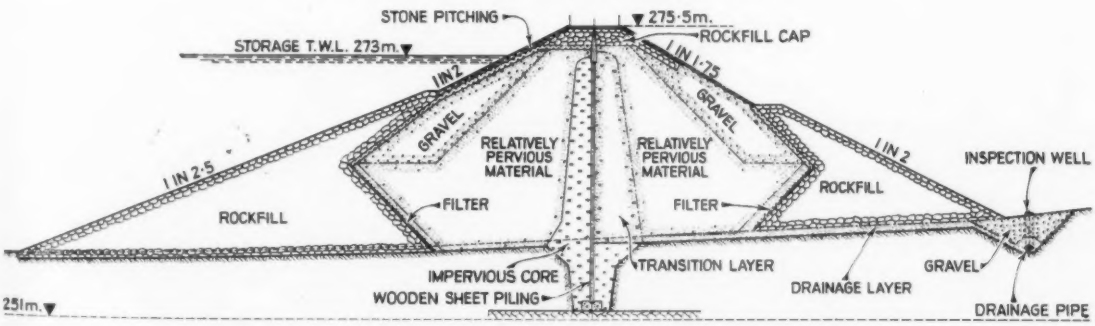


Fig. 3. Section through earthfill section of Storfinnforsen dam

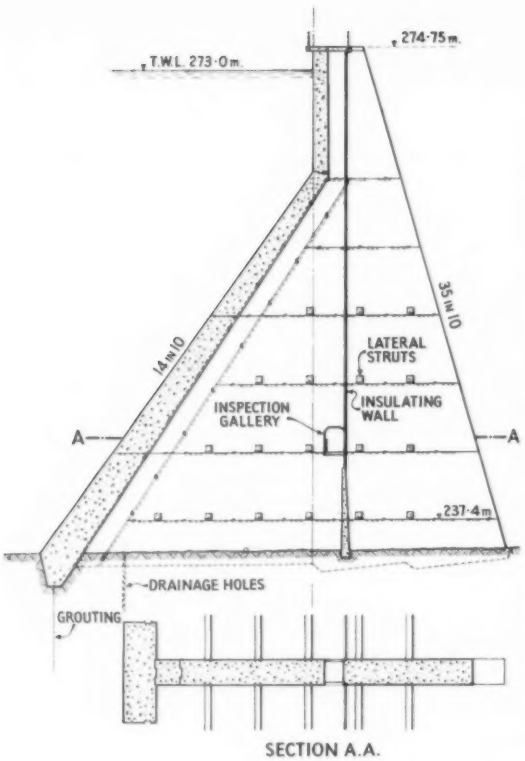
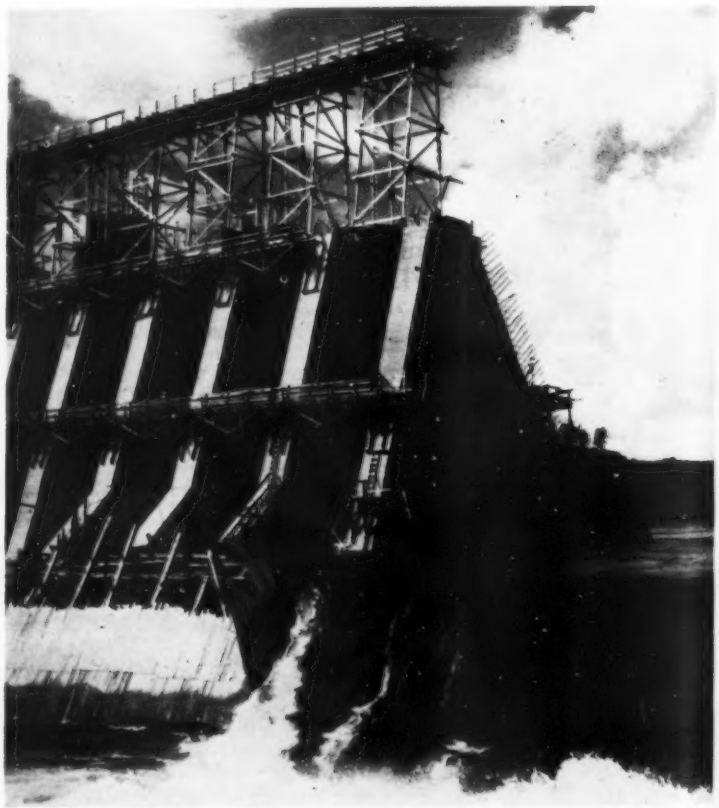


Fig. 4 (above). Section through buttress section of Storfinnforsen dam

Fig. 5 (right). Buttress section under construction



chased the water rights on the Fax river, a tributary of the Ångerman. The Ångerman catchment was described in some detail in our June 1955 issue, but it is worth recapitulating certain points of direct concern to our present study.

The headwaters of the Ångerman are derived from an extensive network of lakes in the mountain range dividing Sweden from Norway. The Ångerman itself has two main tributaries — the Fjällsjö, lying to the west and joining the Ångerman at Åkvisslan, and the Fax, lying still farther west and joining the Ångerman at Osterås some 35 km. below Åkvisslan.

The river Fax derives from six major high-level lakes—Limingen in Norway and Kvarnbergsvattnet, Stora Blåsjön, Jormvattnet, Hetögeln-Fågelsjön and Ströms Vattudal in Sweden. The water from these lakes descend to lake Sporrsjö (elevation 275 m.) from which the river Fax forms the main outlet. There is, however, a second outlet, the Vängel, which lies north of the Fax and is a tributary to the Fjällsjö.

The natural summer flow of the Fax averages 550 cu. m. per sec. and has reached 800 cu. m. per sec., the natural winter flow being as low as 30 cu. m. per sec. Since the completion of Storfinnforsen power station, to be described later, the regulated winter flow has risen to 150-180 cu. m. per sec. As explained in our earlier article, there is an agreement between the owners of the water rights on the Fax, the Fjällsjö and the Ångerman to divert 18 per cent. of the flow from lake Sporrsjö to the Vängel for the benefit of the power stations on the Fjällsjö and the Ångerman, and a regulating dam has been built to give effect to this. The total storage now available in lakes and reservoirs is 2,300 million cu. m. from a drainage area of 6,500 sq. km. Of this, the main storage is in the mountains; the Storfinnforsen reservoir is intended only for daily and weekly regulation, and the reservoir level fluctuates only to the extent of about half a metre.

The first developments on the Fax were two 10 MW stations built some 40 years ago, one by Kramfors AB at Edsele and one by AB Graningeverken at Forse. The utilisation on a larger scale of the power resources of the Fax did not begin until the 1940's. The first large station was built by Hjälta Power Company at Hjälta near the junction of the Fax and the Ångerman, having a capacity of 165 MW. Next in turn was the Storfinnforsen station which lies 80 km. upstream of Hjälta and forms the subject of this article. It has a capacity of 105 MW and was completed in 1954. An even larger station is under construction by the Krån-

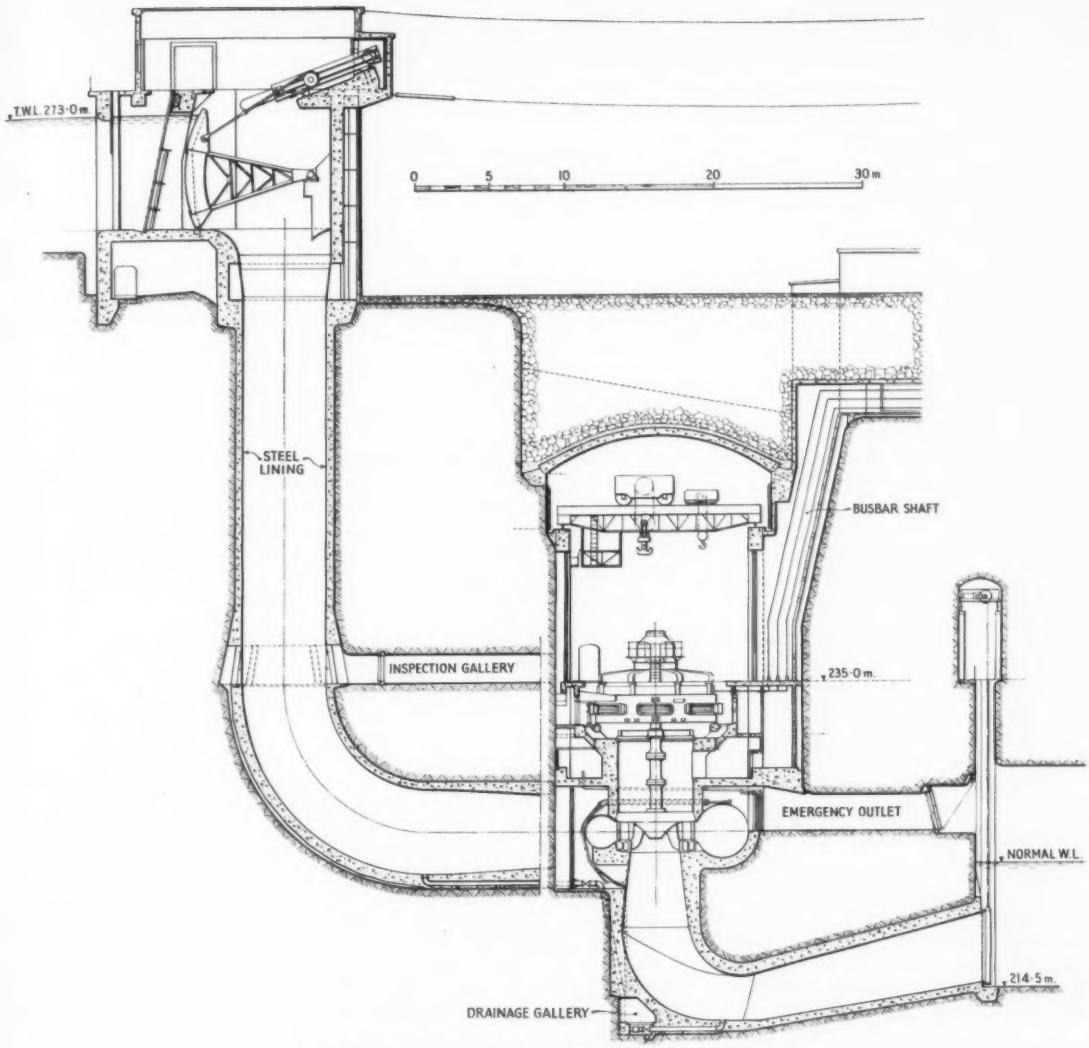


Fig. 6. Section through Storfinnforsen power station

gede Company at Ramsele, 11 km. downstream from Storfinnforsen, which will have a capacity of 150 MW and is expected to be put into operation in 1958.

Storfinnforsen Dam

Storfinnforsen dam impounds a reservoir 30 km. long and 26 sq. km. in area, and creates a net head of 48·5 m. A plan of the layout of the dam and power station is given in Fig. 2, from which it will be seen that the dam has been built in three legs, the left-hand leg being of earthfill construction and the remainder of the dam in concrete. Near the left-hand extremity of the concrete portion is the intake structure for the power station, which is located below ground immediately downstream of the dam; next comes the sluice for a log flume, and farther to the right is a spillway section controlled by three gates; finally the dam curves round to form the right-hand leg.

The earthfill dam, a section through which is given in Fig. 3, is 400 m. long and 24 m. high above lowest foundation. At the deepest part of the valley covered by this dam there is a layer of gravel, and it has been necessary to carry the cut-off trench down to rock. Elsewhere there is a tight earth foundation and the cut-off trench did not need to be carried to such depth. The impervious core consists of a central membrane of wooden sheet piling bedded into concrete at top and bottom and packed on either side with clay for about one quarter of its height. This clay had to be transported from a pit about 25 km. away and its use was correspondingly costly, so above the quarter height the clay was replaced by a very tight moraine. On either side of this impervious core is a layer of semi-pervious material, succeeded by a filter flanked by rockfill. On the downstream side a bottom drainage layer leads to a drainage sump at the toe of the dam. The earth dam absorbed about 170,000 cu. m. of material.

The concrete dam, seen in Figs. 1, 4 and 5, is 800 m. long and 40 m. high above lowest foundation, and is stated to be the largest concrete dam in Sweden. As will be seen from the section, Fig. 4, it is of the

plate buttress type, designed with straight surfaces to secure economy in the use of formwork. Wooden form panels were designed which could be used 20-30 times. The contraction joints were made with copper sealing strips supplemented by asphalt seals. Steel tubes covered with asphalt were built temporarily into the joints, and when the blocks concerned were completed these tubes were steamed and withdrawn, the hole being filled with hot asphalt to be set under air pressure when the whole dam was completed. About 100,000 cu. m. of concrete was used in the construction of this dam.

A double boom floating on the surface of the reservoir directs floating logs to the timber flume, which is controlled by a 6·5 m. sluice and can handle 10,000 logs per hour.

Of the three spillway sections (see Fig. 1) the first is 12 m. wide and is fitted with a sector gate, which can be lowered to float timber—in case of need—and ice as well as to pass flood water. Each of the two remaining sections is 20 m. wide and is provided with a tainter gate, with rising movement only.

Penstocks, Power House and Tailrace

A section through the power house is given in Fig. 6, from which it will be seen that it follows the recognised Swedish practice of an underground station served by vertical pressure shafts and discharging to a tailrace tunnel. There are three generating sets, and flow to each machine is controlled by a hydraulically operated tainter gate 8 m. high by 14 m. wide. Each pressure shaft is 5·7 m. in diameter and is steel-and-concrete lined. At the bottom of the vertical portion an inspection adit affords access to the outside of the steel lining, which is designed to take the full hydraulic pressure. To empty the penstock a drain pipe is taken down to the bottom of the draught tube. An inspection passage is also provided for each discharge ring, and easy inspection is also afforded to the turbine casings as they are only half embedded. Any flood that may arise due to a burst in the hydraulic system is automatically evacuated to the tailrace tunnel through an emergency outlet.

The machine hall is 65 m. long, 12·5 m. wide and 20 m. high. As the rock in the region of the roof was weathered and shattered, construction by normal tunnelling methods was inadvisable, and the hall was excavated by open cut, using a dragline to reach sound rock. When excavation had been completed the concrete arched roof of the hall was constructed and the cavity backfilled.

Heavy equipment is transported to the machine hall by way of an assembly hall which forms part of the surface buildings and which communicates with one end of the machine hall through a large open vertical shaft. A 75-ton crane in the assembly hall lowers the equipment through this shaft to the machine-hall floor, whence it is picked up by the machine-hall crane.

The tailrace tunnel is 150 sq. m. in section and 375 m. long and is of the free-flow type. It is succeeded by an open channel 375 m. long.

(To be continued)

Lining a High-Pressure Shaft

The Mitchell Construction Company, using a sliding shutter, recently completed the lining of the high-pressure shaft serving the turbines of Ceannacroc generating station—part of the Glen Moriston hydro-electric scheme—for the North of Scotland Hydro-Electric Board. Stringent programme requirements made it necessary to execute this work under appalling weather conditions with air temperatures dropping as low as 12° F.

Ordinary Portland cement was used in the specified 1 : 4 mix, both the fine and coarse aggregates being crushed granite road-hauled from the Mitchell Construction Company's site quarry at Cluanie dam. Aggregates and cement were stock-piled to complete the shaft so that even in the event of the site access road becoming impassable due to the weather conditions there would be no hold up. Water was pumped up 180 ft. from the River Moriston into a settling tank adjacent to the mixing plant.

Arrangements had been made for heating the aggregates and water, but owing to the severe weather conditions and the fact that the only possible location of the mixing plant was on a steep hillside, difficulties were experienced in maintaining a steady supply of concrete to the shutter.

Concrete was transported through an adit and tunnel to the head of the high-pressure shaft in tunnel transit cars and discharged into a ¼ cu. yard bottom-opening skip of special design.

The circular section of the shaft is 120 ft. deep and 12 ft. 6 in. finished diameter with a minimum concrete thickness of 6 in. to clearance line. Due to the nature of the rock there was unavoidably considerable overbreak and the wall thickness averaged 17 in.

The shutter was specially designed to resist eccentric loading due to overbreak, but allowed for breaking down into four main sections to pass through the adit and tunnel. It was then lowered piecemeal by a winch to the bottom of the shaft where it was assembled ready for climbing. It formed a steel drum, internally braced, 6 ft. deep with top and bottom platforms. The shutter was fitted with six hydraulic climbing jacks equally spaced and bolted to cantilevered brackets which so positioned the jacks that the embedded jack rods had a 2 in. concrete cover. The jacks were operated from the bottom platform, leaving the top platform free for receiving and placing the concrete, which was dumped from the skip, shovelled into place and tamped.

A valve manifold installed in the hydraulic system permitted isolation of any of the jacks, and these were actuated by a manually operated pump. The jacks climbed on 1 in. diameter bright steel rods with threaded ends which were screwed together as the shutter rose.

In the early stages trouble was experienced due to the jacks sticking, thus throwing the shutter off line and out of level, but this fault was soon corrected.

The low temperatures prevailing throughout affected the concrete and progress was thus unavoidably slow. However, excluding the time taken in adjusting the jacks and relevelling the shutter at the start, an average speed of climb of 7 in. per hour was achieved, the total climbing time being approximately 200 hours.

Calculating Flow through Turbines

Sigfrid Andersson now makes a statistical investigation of the degree of accuracy obtainable with the method explained in his previous article

PART TWO

THE reason for this statistical investigation was to try and ascertain whether the formula previously derived gave quite the same degree of accuracy as the planimetration procedure; such an investigation is probably necessary before the method could be generally accepted by turbine manufacturers and customers, and should also be useful in other cases, e.g., when calculating areas of surfaces by planimetration. When drawing up efficiency guarantees, especially for large turbines, any error may represent a rather important amount of bonus or penalty if the guarantees are above or below their previously fixed limits. In this case, it is desirable, first, that the efficiency be fixed as exactly as possible, and second, that the cost of testing does not become prohibitive. For small power stations, built with limited resources, the situation may well be different, for it is probably necessary to use a rapid and cheap, but still reliable calculation method to keep the cost of testing down.

To investigate the degree of accuracy obtained in drawing and planimetring curves, a statistical survey is necessary as these methods depend upon several factors that are previously unknown. In Fig. 1 the velocity vectors $v_1, v_2 \ldots v_7$ for seven horizontals have been drawn to the nearest millimetre and the vector points joined by a curve. In the present case, the curves were drawn by 26 different people. Actually the 26 people should have marked off the vectors themselves, and the latter should then have been given in decimals of a millimetre; in this way the setting off error would have been included, as it ought to be (then the scatter would probably have been greater). How-

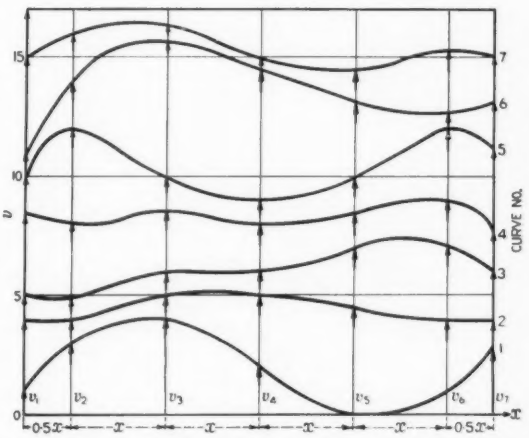


Fig. 1. Approximate shape of curves 1-7 drawn by 26 persons

TABLE V—DEVIATIONS $v_m - v_m$ IN CM. OF AVERAGE VELOCITY VECTORS CALCULATED BY MEANS OF $4 \times 6 = 24$ PLANIMETRATIONS OF EACH CURVE

Person No.	Curve No. 1	2	3	4	5	6	7	$\sum_1^7 \bar{v}_m - v_m$	$\frac{1}{7}\sum_1^7 \bar{v}_m - v_m$
1	+0·010	+0·020	−0·025	−0·016	+0·008	−0·046	+0·022	−0·027	−0·004
2	+0·005	+0·005	+0·029	−0·020	−0·037	+0·004	−0·014	−0·028	−0·004
3	−0·005	−0·015	+0·004	+0·003	+0·025	−0·046	+0·009	−0·025	−0·004
4	−0·003	+0·006	+0·013	+0·002	−0·027	−0·003	−0·007	−0·019	−0·003
5	−0·014	−0·023	−0·015	+0·003	−0·060	−0·023	−0·021	−0·153	−0·022
6	−0·009	−0·009	0·000	+0·014	−0·015	−0·011	+0·021	−0·009	−0·001
7	−0·004	+0·008	+0·011	+0·034	+0·018	+0·019	−0·007	+0·079	+0·011
8	+0·005	−0·005	−0·001	+0·002	−0·005	+0·019	−0·010	+0·005	+0·001
9	−0·013	−0·006	+0·010	−0·002	−0·045	−0·025	+0·004	−0·077	−0·011
10	−0·018	−0·022	+0·001	+0·002	+0·010	+0·011	−0·026	−0·042	−0·006
11	−0·008	−0·001	+0·002	+0·013	−0·006	−0·016	−0·001	−0·017	−0·003
12	+0·040	+0·009	+0·015	+0·023	+0·032	−0·001	−0·003	+0·115	+0·016
13	−0·026	−0·021	+0·006	−0·015	+0·018	+0·012	+0·009	−0·017	−0·002
14	−0·011	−0·002	−0·028	−0·027	−0·055	+0·021	−0·003	−0·105	−0·015
15	−0·004	+0·020	−0·003	+0·023	−0·016	+0·049	−0·004	+0·065	+0·009
16	−0·002	−0·001	+0·013	+0·005	+0·014	+0·023	+0·002	+0·054	+0·008
17	−0·004	−0·005	+0·005	+0·024	+0·035	+0·016	+0·009	+0·080	+0·011
18	+0·020	+0·015	+0·006	+0·001	+0·001	−0·003	+0·021	+0·061	+0·009
19	+0·012	+0·019	+0·006	−0·008	+0·003	−0·048	−0·028	−0·044	−0·006
20	+0·012	+0·030	+0·022	+0·022	+0·044	−0·004	+0·008	+0·134	+0·019
21	+0·012	−0·004	−0·007	+0·009	+0·021	+0·014	+0·010	+0·055	+0·008
22	+0·007	−0·012	+0·005	+0·001	+0·011	+0·010	+0·011	+0·033	+0·005
23	−0·009	−0·017	−0·009	−0·020	−0·001	−0·026	+0·015	−0·067	−0·010
24	+0·006	+0·010	−0·027	−0·010	+0·005	+0·009	−0·008	−0·015	−0·002
25	0·000	−0·002	−0·041	−0·048	−0·017	+0·032	+0·027	−0·049	−0·007
26	+0·024	+0·013	+0·003	−0·015	+0·048	+0·001	−0·031	+0·043	+0·006

TABLE VI—AVERAGE VELOCITY VECTORS v_m IN CM., RANGED ACCORDING TO INCREASING VALUE AND CALCULATED BY MEANS OF 4 × 6 = 24 PLANIMENTRATIONS OF EACH CURVE

Curve No.	1		2		3		4		5		6		7	
	13	0·476	5	0·486	25	0·147	25	0·334	5	0·442	19	0·916	26	0·335
	10	0·484	10	0·487	14	0·160	14	0·355	14	0·447	1	0·918	19	0·338
	5	0·488	13	0·488	24	0·161	2	0·362	9	0·457	3	0·918	10	0·340
	4	0·489	23	0·492	1	0·163	23	0·362	2	0·465	23	0·938	5	0·345
	9	0·489	3	0·494	5	0·173	1	0·366	4	0·475	9	0·939	2	0·352
	14	0·491	22	0·497	23	0·179	26	0·367	25	0·485	5	0·941	8	0·356
	23	0·493	6	0·500	21	0·181	13	0·367	15	0·486	11	0·948	24	0·358
	6	0·493	9	0·503	8	0·187	24	0·372	6	0·487	6	0·953	4	0·359
	11	0·494	8	0·504	6	0·188	19	0·374	11	0·496	20	0·960	7	0·359
	3	0·497	17	0·504	10	0·189	9	0·380	8	0·497	4	0·961	15	0·362
	7	0·498	21	0·505	11	0·190	22	0·383	23	0·501	18	0·961	12	0·363
	15	0·498	14	0·507	15	0·191	18	0·383	18	0·503	12	0·963	14	0·363
	17	0·498	25	0·507	26	0·191	4	0·384	19	0·505	26	0·965	11	0·365
	16	0·500	16	0·508	3	0·192	8	0·384	24	0·507	2	0·968	16	0·368
	25	0·502	11	0·508	17	0·193	10	0·384	1	0·510	24	0·973	9	0·370
	8	0·507	2	0·514	22	0·193	3	0·385	10	0·512	22	0·974	20	0·374
	2	0·507	4	0·515	19	0·194	5	0·385	22	0·513	10	0·975	13	0·375
	24	0·508	7	0·517	13	0·194	16	0·387	16	0·516	13	0·976	17	0·375
	22	0·509	12	0·518	18	0·194	21	0·391	7	0·520	21	0·978	3	0·375
	1	0·512	24	0·519	9	0·198	11	0·395	13	0·520	17	0·980	21	0·376
	19	0·514	26	0·522	7	0·199	6	0·396	21	0·523	7	0·983	22	0·377
	20	0·514	18	0·524	4	0·201	20	0·404	3	0·527	8	0·983	23	0·381
	21	0·514	19	0·528	16	0·201	15	0·405	12	0·534	14	0·985	18	0·387
	18	0·522	1	0·529	12	0·203	12	0·405	17	0·537	16	0·987	6	0·387
	26	0·526	15	0·529	20	0·210	17	0·406	20	0·546	25	0·996	1	0·388
	12	0·542	20	0·539	2	0·217	7	0·416	26	0·550	15	1·013	25	0·393
	$\bar{v}_m$ =	0·502		0·509		0·188		0·382		0·502		0·964		0·366

Median ———— Average Value —— —— —— —— Acceptable Limits – – – – – – – – – – – –

ever, the author did not wish to submit the 26 people to this additional work, which is perhaps regrettable. Nevertheless, it will be clear from the following that in spite of this simplification, the planimetration procedure is eliminated by the derived formula.

The area below each of the curves was planimetered by the author 24 times, and the resulting average velocity vector v_m estimated in centimetres. This average value v_m of these 26 average velocity vectors must be regarded as the most probable exact value. A check on this could have been obtained if a planimetration had been made for the area on the opposite side of the curve, as the sum of these two areas is then a rectangle, the area of which is exactly known, provided due allowance is made for errors in the paper. This investigation was omitted, however, because it is not quite reliable, and, in practice, possible systematic errors can cancel each other out by being positive in one case and negative in the other, whereupon the check on the average velocity vector v_m would be misleading. Such an investigation also requires a good deal of work.

In Table V the variations from the average value v_m have been tabulated and in Table VI the average velocity vectors have been arranged in increasing numerical value, and the reference numbers of the 26 people included. The median has then been drawn between the two middle values, as the number of observations in this case is an even number. As may be seen, the median diverges considerably from the average values of most of the curves which is probably due to the limited material used. In fact, a normal distribution in which the median and the average value coincided would be most unusual, but, from this table each of the 26 persons can see how many curves he or she has managed to include within given limits, which have been taken at about two-thirds of the variation width, as shown by the broken lines.

It is worth noting that the curves used have not been extrapolated at the end positions as would be done in a water-volume measurement, but this would probably only be advantageous when using the planimetration procedure. As has already been mentioned, this part of the curve in the formula has been represented by an extrapolated parabola of the second degree, which probably reproduces the true smooth

TABLE VII—AVERAGE VELOCITY VECTORS v_m IN CM. CALCULATED BY MEANS OF 4 × 6 = 24 PLANIMETRATIONS OF EACH CURVE

Person No.	Curve No. 1	2	3	4	5	6	7
1	42·3 42·3 43·0 39·6 39·2 39·2 $\frac{245{\cdot}6}{480}$ = 0·512	42·5 44·0 44·2 41·4 40·7 41·0 $\frac{253{\cdot}8}{480}$ = 0·529	12·6 15·3 15·8 11·8 11·9 10·6 $\frac{78{\cdot}0}{480}$ = 0·163	29·1 30·8 31·0 28·6 28·2 27·9 $\frac{175{\cdot}6}{480}$ = 0·366	41·7 41·6 42·5 41·1 38·8 39·0 $\frac{244{\cdot}7}{480}$ = 0·510	73·4 74·1 73·7 73·4 73·8 72·3 $\frac{440{\cdot}7}{480}$ = 0·918	31·0 31·2 31·5 30·7 31·0 30·8 $\frac{186{\cdot}2}{480}$ = 0·388
2	43·0 41·8 41·7 40·2 38·0 38·7 0·507	40·8 41·9 43·8 38·5 40·0 41·8 0·514	18·4 17·9 18·4 14·9 16·5 18·0 0·217	30·5 30·9 29·3 27·3 28·2 27·6 0·362	39·8 40·0 38·7 35·3 34·8 34·7 0·465	77·6 78·1 78·7 76·2 77·3 76·8 0·968	30·0 28·5 29·2 27·6 26·2 27·3 0·352
3	40·7 41·4 41·7 39·5 37·5 37·7 0·497	40·5 40·9 40·6 39·6 37·8 37·5 0·494	16·0 17·0 16·6 14·6 15·0 13·0 0·192	31·5 32·5 32·4 29·2 29·2 30·0 0·385	43·6 44·3 45·4 40·0 39·6 40·0 0·527	75·2 74·4 74·4 71·7 72·1 73·0 0·918	31·0 30·3 29·7 30·0 29·6 29·3 0·375
4	39·6 41·0 40·0 39·4 37·3 37·2 0·489	42·7 42·1 41·3 39·8 40·4 41·0 0·515	17·2 17·1 17·1 15·2 15·1 14·8 0·201	31·5 31·8 31·9 30·2 29·3 29·5 0·384	40·2 40·4 40·7 35·8 35·3 35·3 0·475	76·4 77·7 75·4 75·7 78·0 78·2 0·961	30·1 28·8 28·2 28·6 29·0 27·7 0·359
5	41·7 40·2 39·8 38·5 37·5 36·7 0·488	40·0 39·7 41·5 37·5 37·7 37·3 0·486	15·4 16·2 15·0 12·9 12·1 11·4 0·173	32·6 32·9 32·5 29·9 27·5 29·2 0·385	36·5 38·2 38·1 33·3 33·1 32·8 0·442	75·8 76·6 76·8 73·8 74·7 73·8 0·941	30·3 29·0 28·2 26·4 26·2 25·5 0·345

profile in a surer manner than if it had been drawn and subsequently planimetered. Furthermore, as the extreme current meter is only approximately 175 mm. from the wall, this source of error is negligible, certainly in normal flow. This case could be considered using either the one method or the other, with velocity profiles with a pronounced downward inclination near the wall (as are obtained when an adjacent machine is running with a considerably greater load than the one being tested). However, the accuracy of the current meter is also involved as the propeller must then work in an area which suffers from variable velocities.

As already mentioned, the area below each of the curves 1 to 7 was planimetered 24 times in order to get a sufficiently exact value of the average velocity vector v_m, each surface being planimetered four times in succession so as to reduce the initial and final errors in the readings. In order to avoid a constant error due to possible parallel errors in the planimeter, the latter was used with the pole weight to the right of the rod for 12 planimetrations and to the left for the other 12; the average value of these readings being used. A sufficiently exact value is thus obtained provided that the parallel error is small. (See "A textbook on the Use and Care of Ott's Compensating Planimeter together with a Brief and Clear Mathematical Theory of Polar Planimetrations in General" by A. Otto Kempten, Bayern 1912). It is clear that our planimeter has suffered from such an error, as the three upper values in each group, almost without exception, are greater than the three lower ones (see Table VII where the values obtained by only five people have been included). When this has not happened the pole weight must have been placed in an unfavourable position, and another error has appeared, as for the "most favourable" position for the planimeter the angle between the pole rod and the planimeter rod should be 90°, with the pin placed in the "centre main point" of the surface.

TABLE VIII—CHECK OF PLANIMETER NO. 34183 BY CONTROL RULER WITH 10 PLANIMETRATIONS MADE IN SUCCESSION FOR EACH VALUE

For $r = 8$ cm. on control ruler, the area will be 201·062 sq. cm.
A means that the pole weight is directed to the right of the rod.
B means that the pole weight is directed to the left of the rod.

	$z = 90°$				
A	202·35	202·36	202·36	$\frac{2427·11}{12} = 202·259$	
B	202·21	202·17	202·19		
A	202·32	202·36	202·34	$\frac{1·197}{201} \cdot 100 = +0·59\%$	
B	202·12	202·17	202·16		
	$z = 68°$				
A	202·40	202·40	202·40	$\frac{2429·31}{12} = 202·443$	
B	202·50	202·46	202·46		
A	202·40	202·40	202·41	$\frac{1·381}{201} \cdot 100 = +0·69\%$	
B	202·50	202·50	202·48		
	$z = 49°$				
A	202·73	202·73	202·73	$\frac{2433·29}{12} = 202·774$	
B	202·82	202·82	202·82		
A	202·71	202·74	202·73	$\frac{1·712}{201} \cdot 100 = +0·85\%$	
B	202·82	202·82	202·82		
	$z = 97°$				
A	202·47	202·42	202·40	$\frac{2427·93}{12} = 202·328$	
B	202·27	202·26	202·25		
A	202·37	202·36	202·40	$\frac{1·593}{201} \cdot 100 = +0·79\%$	
B	202·25	202·23	202·25		

The fact that these errors have appeared and are due to the inappropriate placing of the rod, was confirmed by tests with a control ruler. Ten revolutions were made in succession with the pole rod respectively to the right and to the left, and the values obtained were so nearly equal that the instrument was considered accurate for the purpose (see Table VIII). Yet the fact that somewhat too high values (0·59 per cent.) were consistently obtained even in the supposed most favourable position for the rod, shows that the planimeter was not accurately adjusted, provided, of course, that we assume the control ruler to be correct. In order to check this latter point some further tests were made with another control ruler, and these tests gave an error only 0·01 per cent. greater than the previous tests; thus we may assume that both control rulers were accurate.

A check of all the curve paper used, made with an accurate ruler, showed the paper dimensions to be smaller than they ought to be, averaging 0·04 per cent. in the *Y* direction and 0·2 per cent. in the *X* direction for curves 1 to 5, and 0·09 per cent. in both directions for curves 6 and 7. As the faults are very small and that part of the surface planimetered is larger in the *X* direction (by ten times) than in the *Y* direction, it may be shown that it is adequate to correct only in the *Y* direction by 0·04 per cent. and 0·09 per cent. respectively. Thus a negative correction of 0·59 minus 0·04 equalling 0·55 per cent. was made to the average velocity vector v_m for the curves 1 to 5, and a correction of 0·59 minus 0·09 equalling 0·50 per cent. to the curves 6 and 7, before using the values tabulated in Table IX.

The deviations in the curves 1 to 7 thus include both drawing and planimetration errors, and these have been plotted in Fig. 2. As may be seen, no well defined frequency curves of deviation have been obtained due to the lack of material, but the trend towards a normal division may be seen. Due to the fact that the pole weight was in his case placed in only one direction, the deviations show an obvious positive displacement with only four planimetrations, and it will be clear from the diagrams that the variation width has changed from, for example, 0·110 cm. for 24 planimetrations to 0·143 cm. with one planimetration, the insignificance of which could not have been forecast.

In Fig. 3 the deviations for each curve have been added and then divided by seven, as a turbine test can generally be considered to have at least seven horizontals. This addition of the deviations may give some idea of the errors that might be expected on adding the horizontals after making the approximation, so that all horizontals have the same effect. Again, we can see that the variation width has changed only slightly from 0·041 cm. to 0·049 cm. for 24 and 1 planimetrations respectively.

We may thus say that starting with a possible error of 5 per cent. the probable maximum deviation of the sum of all horizontals would be approximately $\pm$ 0·025 cm., this being independent of the number of planimetrations. In the same manner, we can obtain for the summation curve, Fig. 2, a possible deviation of about

TABLE IX—AVERAGE VELOCITY VECTORS OBTAINED IN CM.

Curve No.	Integration	Average value of 26 curves approximately alike, each planim. 24 times	Average value of 8 curves exactly alike, each planim. 24 times	Author's formula	Average value of 7 curves approximately alike, each planim. 24 times	Simpson formula in ordinary and special execution
1	2·000	1·999		2·000		2·000
2		4·506		4·504		4·479
3		6·187		6·181		6·142
4		8·380		8·378		8·367
5		10·499		10·522		10·633
6		13·959		13·963		13·977
7		15·364		15·341		15·345
6a			3·940	3·963		3·977
7a			1·348	1·341		1·345
8			1·232	1·239		1·229
9			1·418	1·421		1·442
10			4·855	4·862		4·151
11			6·640	6·646		6·762
8b				1·239	1·246	1·229
9b				1·421	1·426	1·442
10b				4·862	4·850	4·151
11b				6·646	6·652	6·762
12	0·457			0·454		0·422
13	6·667			6·667		6·667
14	5·716			5·720		5·722
15	4·314			4·314		4·315
16	2·698			2·699		2·702
17	3·953			3·960		3·984
18	2·830			2·828		2·822
19	1·413			1·413		1·409
20	1·473			1·472		1·470
12:1	0·287			0·287		
13:1	7·392			7·392		
14:1	5·070			5·074		
15:1	3·476			3·477		
16:1	2·059			2·059		
17:1	3·639			3·641		
18:1	3·195			3·194		
19:1	1·588			1·588		
20:1	1·212			1·212		
12:2	0·346			0·354		0·352
13:2	7·867			7·867		7·867
14:2	5·069			4·906		5·073
15:2	4·213			4·210		4·212
16:2	2·568			2·565		2·567
17:2	4·313			4·276		4·300
18:2	2·885			2·899		2·889
19:2	1·568			1·572		1·569
20:2	1·102			1·106		1·103

± 0·050 cm. for 1, 2 or 4 planimetrations, and about ± 0·040 cm. for 8 and 24 planimetrations. The probable maximum deviation, if the average velocity is 1 m. per sec. and the velocity scale 10 cm. to 1 m. per sec., will thus be approximately ± 0·075 cm. corresponding to about 0·8 per cent. error. However, the error risk will then only be $\frac{1}{2}\left(\frac{5}{100}\right)^2 = 0{\cdot}13$ per cent. as may be shown by using the multiplication theory of the calculus of probability. The factor of one-half was used as there are two cases of four possible combinations that can give a maximum (positive or negative) error.

The curves 6a, 7a and 8-11 in Fig. 4 were drawn by the author, and each curve entered only once. The curves 6a and 7a were drawn from the same vectors as curves 6 and 7, whereas 8-11 were drawn at random. The average velocity vector for each curve was estimated by means of 8 × 24 = 192 planimetrations, on the assumption that there were 8 curves exactly alike, one of which was planimetered 24 times. Thus the deviations for these eight groups of exactly similar curves consist of planimetration errors only, and these are shown plotted in Fig. 5 as for previous curves. For 24 and two planimetrations respectively, the variation width is modified from 0·026 cm. to 0·054 cm. Thus an increased number of planimetrations seems to be useful in this case, which is hardly the case with curves 1-7.

The reason why the velocity vectors for the curves 6a and 7a were taken from 6 and 7 was only to try to get some examples of an exactly determinable drawing error, though it would appear that even so these were not obtained. On the other hand, reading errors do not exist, because the velocity vectors were given in whole numbers of millimetres. As mentioned before, the average velocity vectors for the curves 6 and 7 should be considered to be the correct values, as according to the above, the curves 6a and 7a were also planimetered 8 × 24 = 192 times, and the average velocity vectors of these must be considered as accurately determined. It will be clear from Table IX that rather large deviations are obtained, but it must be pointed out that no check on the most favourable planimeter-pole position was made in these tests, and therefore there is the possibility of a systematic kind of error in the four cases, in spite of the great number of planimetrations. In fact, the author, in carrying out all these planimetrations, was very conscious of the fact that the planimeter was preferably placed in a specially determined way, depending, among other things, on the shape of the curve and its position on the paper; this position is not necessarily always the most favourable,

and therefore there is always a risk of the above-mentioned systematic errors.

Curves 8b-11b were planimetered 24 times and drawn by seven persons, after the author had measured as accurately as possible the velocity vectors from the curves 8-11 drawn at random, and set them off on the 7 mm. paper. As the vectors in this case are quite close to each other (almost the same as in a real test), it is hardly of interest to show a greater number of this type of example. In fact, it appears from the deviations shown in Fig. 6 that almost exact curves might be expected. If this had not been the case, we would have obtained four examples of differences between the assumed real average velocity vectors (curves 8-11) and those obtained (curves 8b-11b) by increasing the number of examples. In fact, it is not very likely that a real curve, which may be represented by only a few points, will ever be exactly reproduced, even if it is drawn by a great number of people. One cause of this is that certain given points are often considered as the maximum or minimum values of the curve, which is not always the case, but for want of other reasonable possibilities, this must still be considered as the most natural thing in such a case. On account of the small distance between the vectors, the above discussion is of no importance in this case, which is as might be

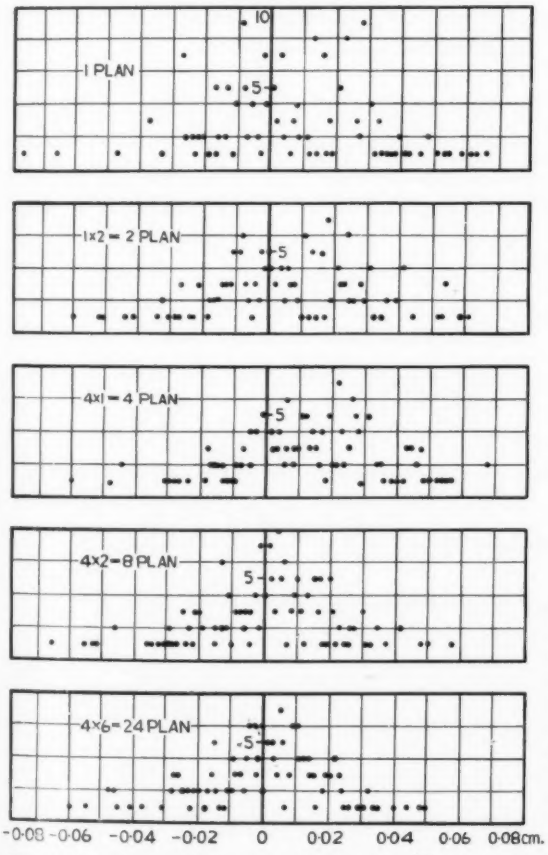


Fig. 2. Frequency diagram of deviations $\bar{v}_m - v_m$ *for curves 1-7 at varying numbers of planimetrations. Total number of curves* $7 \times 26 = 182$

First figure indicates number of revolutions planimetered in succession before each reading

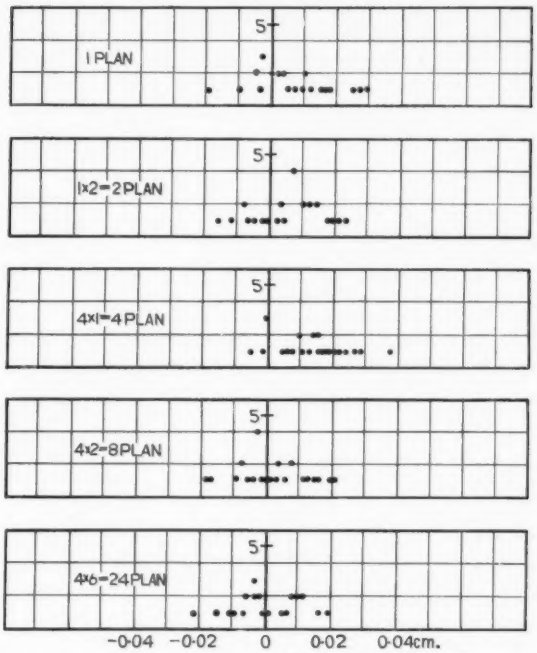


Fig. 3. Frequency diagram of deviations $\frac{1}{7}\sum_1^7 \bar{v}_m - v_m$ *for curves 1-7 at varying numbers of planimetrations. Total number of curves 26*

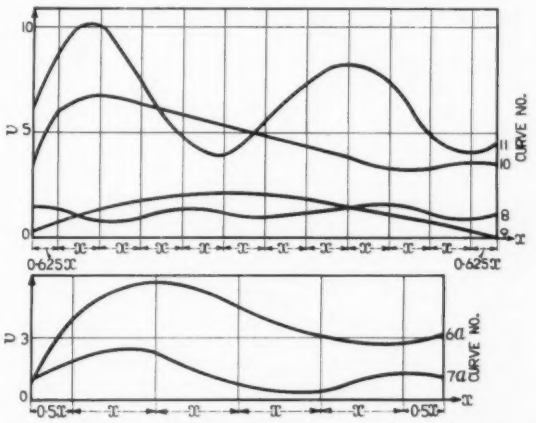


Fig. 4. Curves 6a, 7a and 8-11 assumed to be exact

expected and will also be evident from the following investigation. It should also be noted that the author has included the curves 8b-11b despite the meagre results they give. The average velocity vectors for the curves 8-11 and 8b-11b diverge probably because of the measuring errors as well as setting out, drawing and planimetration errors, though the first mentioned and, to a large extent, also the second probably caused the main deviation. These few observations (four in number) only give a small idea of the deviations that may be expected in setting out the velocity vectors from given numerical values. This is not quite correct either, as it is not a matter of measuring errors in these cases, but only in the other three cases mentioned.

The curves 1-7, 12-20, 12 : 1-20 : 1 and 12 : 2-20 : 2

which are set out in Figs. 7, 8 and 9 were calculated using the derived formula, the deviations being set out in Fig. 10. In this case, it was necessary to deduce the above formula specially, so that it applied for the division of the velocity vectors used for these curves. This division was chosen so as to simplify the estimation of the velocity vectors for the mathematical curves, which were executed to five decimals and then rounded off to three places. The integrated values were also calculated to five decimals, and therefore the figures to three decimals included in the answer are correct. The deviation for these curves (disregarding curve 14 : 2, where the formula has practically failed) is 0·048 cm., and consequently only about one-third of the deviation for the curves 1-7, the latter being drawn and planimetered as shown in Fig. 2. However, curve 14 : 2 as well as some of the other curves were greatly exaggerated so as to represent an acceptable turbine test, and thus we should not necessarily attach too much importance to the failure. Furthermore, curves 12 : 2-20 : 2 were made with a small increment in the X direction, this being done to test the derived formula "severely" and later also to test the Simpson formula. It is not quite clear from this whether the formula gives a deviation in one direction, even if the deviations are fairly symmetrical around the zero position, as the curves are of a rather random shape. In fact, although this material is not very extensive, a probable maximum variation width approximately equal to that above could be assumed, and therefore any possible deviation in any one direction has no practical importance. The analytical calculation method is also preferred from the accuracy point of view, even though the planimetration be executed in the right manner, for in most cases no great degree of accuracy is expected.

The deviations between the two methods have been within ± 0·1 per cent. for certain actual turbine tests made by Vattenbyggnadsbyrån, Stockholm, which were estimated partly according to the derived formula and partly by means of planimetration; here, also, practicaly the whole deviation could be assigned to the planimetration.

Finally, the curves 1-11, 12-20 and 12 : 2-20 : 2 were calculated using the Simpson formula. For the curves 1-7, 8-11 and 12-20 it was necessary to deduce the Simpson formula specially, as the distance between the two outer velocity vectors is 0·5x for the curves 1-7 and 12-20 and 0·625 x for the curves 8-11. (The Simpson formula is not applicable to the curves 12 : 1-20 : 1, as these contain an even number of velocity vectors.)

As may be seen from the summary in Table IX, a rather curious situation is apparent in that the Simpson formula used with curves 1-7 and 12-20 improves upon the formula only for curve 7. Considering the remainder of the curves, the correctness of the values obtained from curve 7 may be questioned, one possibility being that there is a systematic fault due to inappropriate placing of the planimeter pole weight. Another possibility, which is more plausible, is that the velocity vectors were not read with sufficient care, and thus the value 15·364 may be considered as correct and the other values obtained as incorrect. The derived formula also seems to make curves 8-11 appear more nearly correct (except for curve 8), whereas for the mathematical curves 12 : 2-20 : 2 it tends to the contrary. However, too much notice should not be taken of the average planimetered values for the curves 8-11 as these are only based on one curve. It is not possible to draw any general conclusions from this material as to the accuracy of the two formulae, yet it should be pointed out that it was rather difficult to get the Simpson formula to retain its validity for the majority of the non-mathematical curves 1-11. Whether this was coincidence or not cannot be determined from this investigation. Furthermore, it could only be proved if the velocity profiles in an actual turbine test have "mathematical" shape or are genuinely randon.

Even if the Simpson formula had any advantage over the derived formula, though this is unlikely, it is in any case not very suitable as it requires an odd number of current meters and horizontals, and with a double curvature there is a possibility of the Simpson formula diverging unnecessarily from the curve as it is based on parabolic curves, each of which includes the distance 2x. Moreover, as the Simpson formula does not have the same coefficients between the respective third measuring points (i.e., starting from both sides), it does not give as simple a calculation diagram as the derived formula. From an accuracy

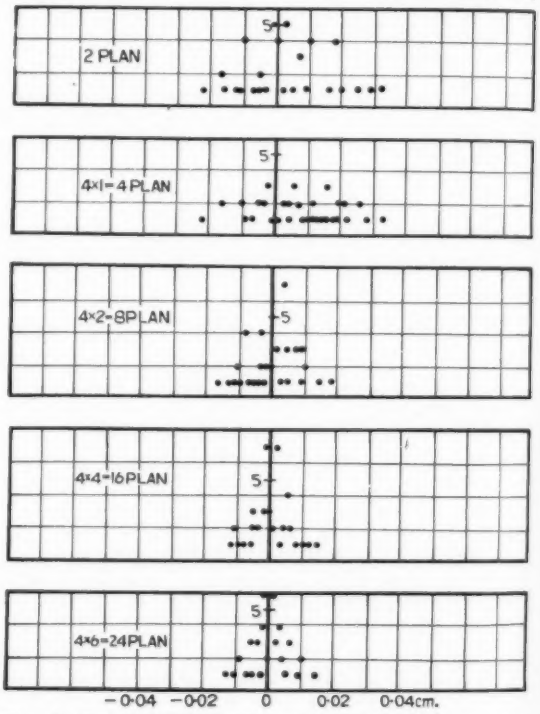


Fig. 5. Frequency diagram of deviations $\bar{v}_m - v_m$ *for curves 6a, 7a and 8-11 at varying numbers of planimetrations. Total number of curves 6 × 8 = 48*

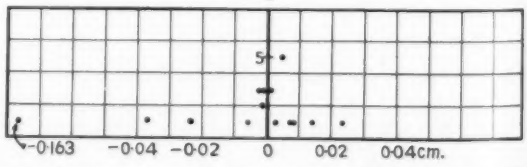


Fig. 6. Frequency diagram of deviations $\bar{v}_m - v_m$ *for curves 8b-11b at 24 planimetrations. Total number of curves 4 × 7 = 28*

point of view, the derived formula is quite sufficient, as the current meters and the horizontals are placed at a distance of only $x \approx y \approx 60$ cm., which, when drawn to scale for planimetration, usually corresponds to about 1·5 to 2·5 cm. This is about half of what was used for most of the curves considered here, and therefore the accuracy will be greater than we managed to obtain in his work. For instance, from the mathematical analysis by J. Malmquist, "Natur och Kultur," Stockholm, 1951, volume 1, pages 555 and 537, the error in the trapezium method is proportional to h^2, and in the Simpson formula h^4 where h is the distance between the starting points. Consequently, in this case one can at least take the first of these into account, the formula being based on the trapezium method. The author is aware of certain slight errors in this work which do not affect its value, yet would take a lot more time to correct. He hopes that he has adequately outlined the degree of accuracy that can be expected in drawing curves and planimetering, using a conventional planimeter and without pushing the matter to impossible extremes.

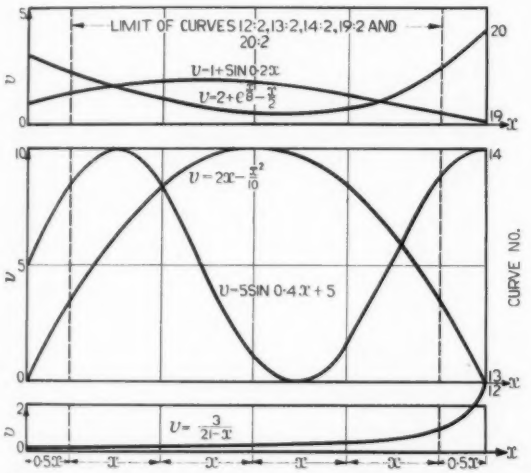


Fig. 7. Mathematical curves 12, 13, 14, 19, 20, 12 : 2, 13 : 2, 14 : 2, 19 : 2 and 20 : 2

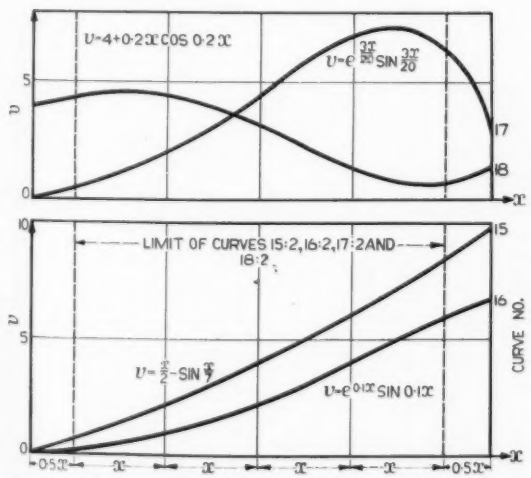


Fig. 8. Mathematical curves 15-18 and 15 : 2-18 : 2

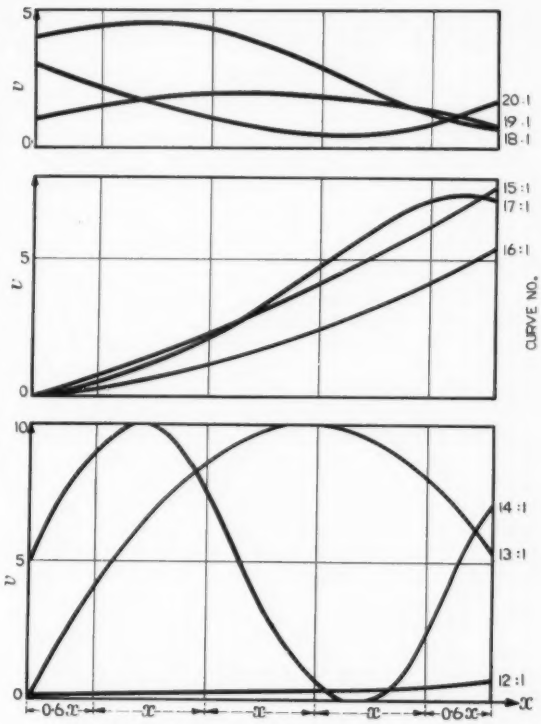


Fig. 9. Mathematical curves 12 : 1-20 : 1

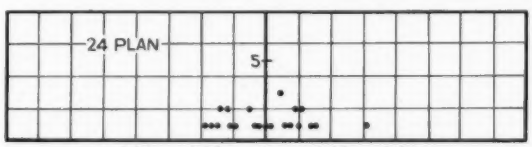


Fig. 10. Frequency diagram of deviations for the author's formula for curves 1-7, 12-20, 12 : 1-20 : 1 and 12 : 2-20 : 2, of which 1-7 have been planimetered 24 × 26 = 624 times each and the others have been integrated. Total number of curves 34

Finally, he wishes to express his sincere thanks to those of his colleagues of the Vattenbyggnadsbyrån, who have contributed wholeheartedly by drawing curves, and also express his very best thanks to Messrs. B. Norsell, M. Hartwig, G. Tengnér and E. Bosrup, with whom he has had such interesting and fruitful discussions. He is also indebted to Professor C. G. H. Esseen of The Royal Institute of Technology, who has revised the manuscript, and last but not least to Mr. N. K. Webb of The English Electric Co. Ltd., who has corrected the English.

Plessiflex Hydraulic Hose. Power Auxiliaries Limited, Swindon, have sent us a copy of a brochure describing the construction and uses of Plessiflex hydraulic hose for the conveyance of liquids or gases at high pressures between junctions subject to vibration or relative movement. The construction is claimed to be entirely novel, and consists of a seamless flexible thin-wall metallic hose covered with a single or double layer of metallic braiding.

Novel Fish-Collecting Facilities

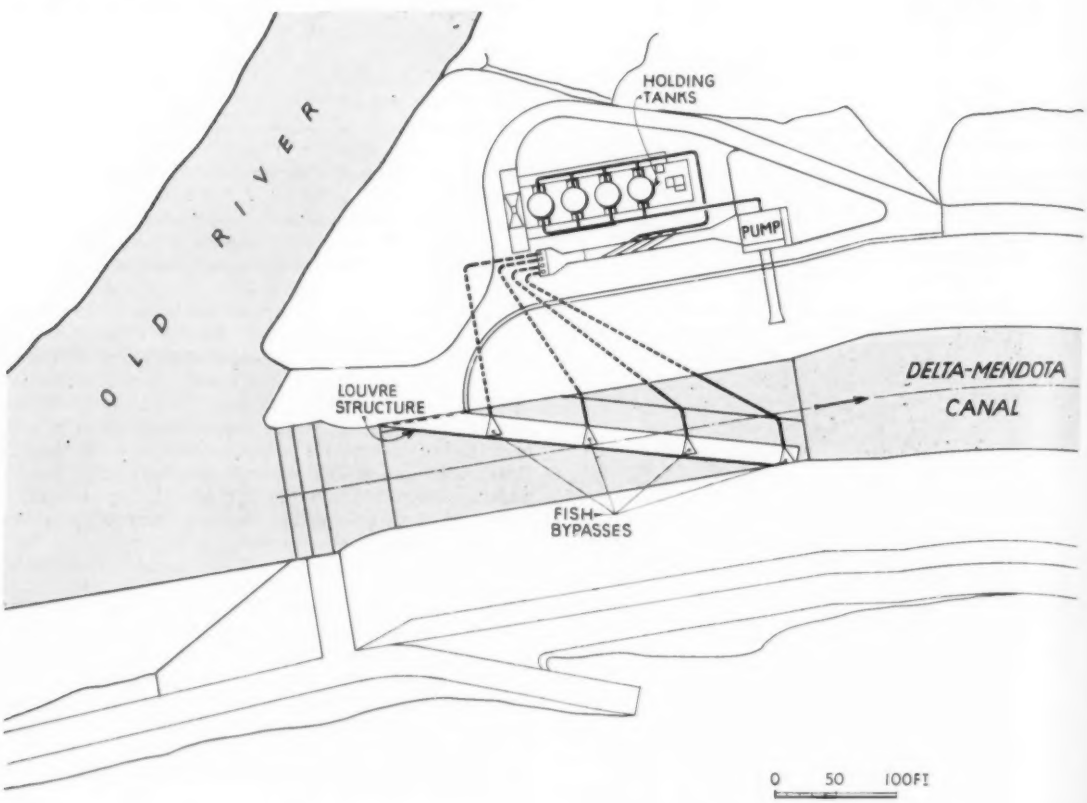
The U.S. Bureau of Reclamation is building a novel fish-collecting installation at the intake to the Delta-Mendota Canal, a major irrigation artery on the Bureau's Central Valley Project

A NOVEL design for fish-collecting facilities is now under construction at the intake to the Delta-Mendota Canal, a major irrigation artery on the Bureau of Reclamation's Central Valley Project in California. The facilities are being built to prevent millions of young fish, mostly salmon, bass, and catfish, as small as one-third of an inch in length, from entering the canal at its intake in the Delta area of the project. A commercial and sporting fishery resource, estimated to be worth $10,000,000 annually, will be protected when the facilities are completed.

In brief, the facilities divert the fish from the main flow of water by means of a row of vertical louvres set 1 in. apart and at right angles to the flow in a structure which extends approximately 340 ft. diagonally across a concrete channel 83 ft. 6 in. wide and about 25 ft. deep. The minute baby fish are carried down the channel by the current. As the fish approach the louvres, they swim to one side to avoid the disturbing eddies and sounds made by them. Although the fish are repelled by the louvres, they readily enter bypass pipes placed at intervals in the louvred barrier. The bypass pipes carry the fish to holding tanks, from which the fish will be counted and transported by trucks 40 to 50 miles to an area where they can swim safely to the ocean.

The Delta region is a maze of tidal channels at the head of San Francisco Bay. The project's Delta Cross Channel, which extends across the 50-mile-long Delta, carries surplus Sacramento River water from the northern end to the southern end of the Delta for delivery to the intake of the Delta-Mendota Canal. Water from the intake is then conveyed 2½ miles to the 4,600 cusec capacity Tracy pumping plant, which lifts the water 197 ft. into the canal for delivery 120 miles south to irrigable lands in the southern area of the Valley. The fish-collecting facilities are being built adjacent to the Old River, which serves as a natural link in the Cross Channel.

The Delta area is the most important spawning and



rearing region for striped bass and shad on the Pacific coast. Young king salmon are found in great numbers in the waters of the Delta where they loiter on their way to the ocean. Catfish are an important sport fish taken in large numbers and spend their life cycle in the Delta waters.

Salmon, bass, and shad are anadromous fish; that is, they spawn in fresh water but spend their adult lives in the ocean. The young fish descend the rivers to the ocean, carried by and following the major flows of water. During periods of low flow in the Old River and when the canal is operated at capacity, the Tracy pumps will take all of the flow of the San Joaquin River entering the Delta from the south and may draw half of the Sacramento River flow. Thus, the major diversion of the Delta-Mendota Canal operating at full capacity would be nearly as great an attraction to these young fish as would the combined flow of the Sacramento and San Joaquin Rivers to the ocean.

The design for the new facilities was developed from studies made on a pilot structure in the field and from model studies in the Denver design offices and laboratories of the Bureau. Travelling fish screens were installed in the pilot structure, but they were discarded in the final design because the continuous operation needed to lift the fish to the holding tanks and to remove large accumulations of peat moss in the channel water quickly wore them out. Development of the final design was a joint effort of the Bureau, the Fish and Wildlife Service of the United States Department of the Interior, and the California State Fish and Game Department and Division of Water Resources.

Devices to protect fish are included wherever necessary on all features of the Central Valley Project. Planned release of cool water from the project's major dams, such as Shasta, Keswick, Nimbus, and Folsom, helps to maintain conditions favourable to salmon.

The $988,116 contract for construction of the new fish-collecting facilities is held by Fred J. Early, Jun., Inc., and John Delphia, of San Francisco.

Harland Expansion Programme

The Harland Engineering Co. Ltd. have opened a new works at Timperley, near Manchester, and have embarked on a £250,000 extension at their Alloa works. In recent years Harland's interests have moved towards the manufacture of heavy tailor-made plant. The Alloa works is an ideal factory for this type of work as there is ample headroom for the movement by heavy cranes of very large units, and the machining equipment includes one of the largest boring mills in the United Kingdom.

As it is obviously uneconomical to produce the company's smaller standard ranges of batch-produced plant in such a factory, a new works has been opened at Timperley, Cheshire, and is now in production. The machine tools of this new works are suitable for dealing with repetitive work and the layout has been carefully planned to assist batch production.

This transfer of the manufacture of small and medium standard pumps to Timperley has been a deliberate step to allow the Alloa works to concentrate on the production of heavy plant, and important extensions are under way to enable the company to manufacture the largest sizes of water turbines and the special plant required in thermal and nuclear power generation.

At present the size of the existing Turbine Bay is being doubled to allow for the installation of additional tools and to provide more fitting space, and the Test Bed is being reorganised and extended. The Fabrication Department has already been doubled in size, and a new plate bending press—which will be the only one of its kind in Britain—will soon be installed to facilitate the fabrication of water-turbine spiral cases from plate exceeding 4 in. in thickness. Another sign of the company's confident expansion into the manufacture of very heavy plant is the building of a new office block (see below) for part of the present staff and the additional personnel who are being engaged.

Butterfly Valves for Eildon

The accompanying photographs show one of two 14 ft. 6 in. diameter butterfly valves built by Glenfield & Kennedy Limited, Kilmarnock, for the Eildon power station of the State Electricity Commission of Victoria, Australia. The valves were manufactured to the order of Boving & Co. Ltd., London, and are the largest of their kind yet made in Britain. When fully assembled each weighs approximately 90 tons. They are designed to withstand a maximum static head of 252 ft. and were hydraulically tested to some 425 ft. When closed under the full head, their doors each sustain a load of about 1,150 tons.

The valves are hydraulically operated and electrically controlled. Construction is essentially of cast steel with gunmetal trim. The bodies are in halves, each weighing some 15 tons, having the jointing flanges on the vertical centre line and the door-shaft trunnions on the horizontal centre line. The doors, each cast in one piece together with their shafts, have an individual weight of about 35 tons. The servomotors, of the vertical type, are principally of cast iron with gunmetal liners and are fitted with adjustable slowing-down devices. The connecting rods are forged steel.

Each valve is provided with an 18 in. diameter hydraulically actuated bypass sluice valve with a solenoid-operated control valve. A similar-sized manually worked sluice valve is also provided in the bypass line, to act as a guard valve for maintenance purposes. A mechanical locking arrangement enables the main valves to be locked securely in the closed position.

Adjustable dismantling joints, of the sliding sleeve form, facilitate erection and dismantling at site, and give rigid connections between the valves and the spiral casings.

Sealing of the valves when fully closed is effected by reinforced rubber sealing hose, inflated by water from the penstocks, fitted to the peripheries of the doors and continued round the upstream sides of the shafts. The hoses make contact with gunmetal faces in the bodies, giving a continuous and efficient sealing arrangement. Pressure relief valves automatically control the pressure to the hoses, and hand pumps are provided for boosting the pressure to them if required.

The valves are operated by pressure water from the penstocks and are controlled through gunmetal balanced-piston-type control valves, actuated by pilot valves through electric solenoids, from the turbine control panels. For opening the valves, water is taken from the downstream side, and for closing from the upstream side. Although, like all turbine isolating valves, they are designed to close under free-discharge

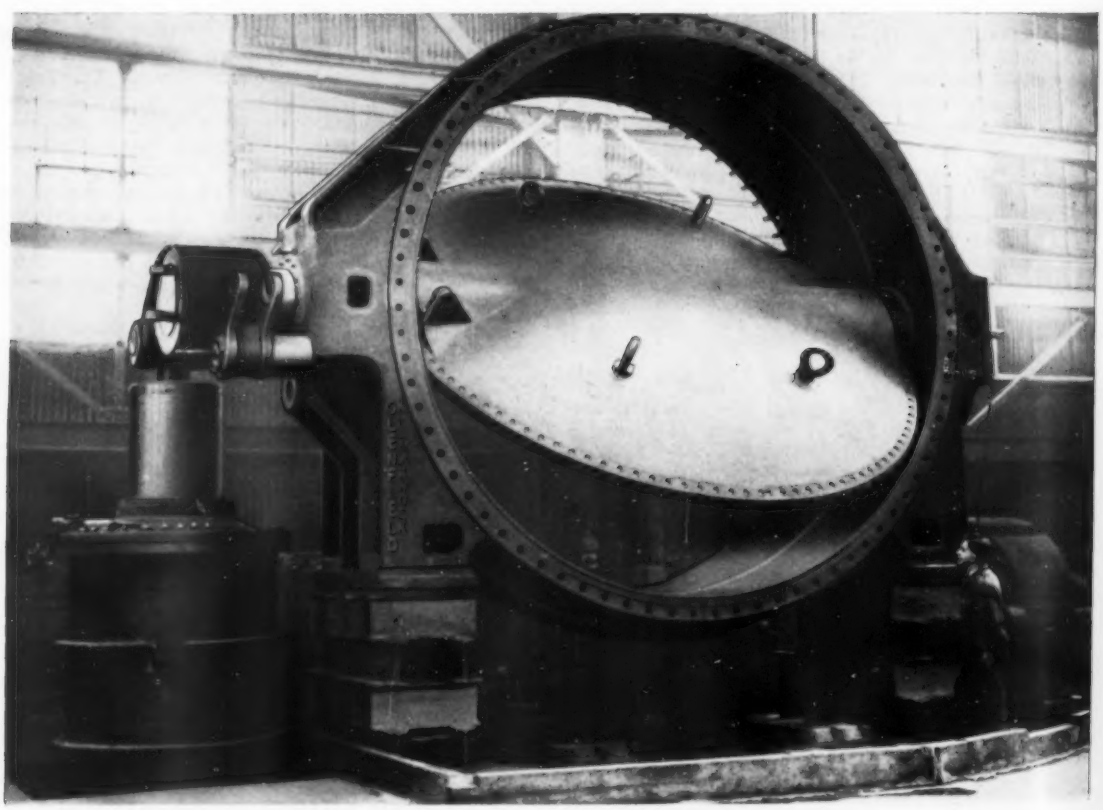
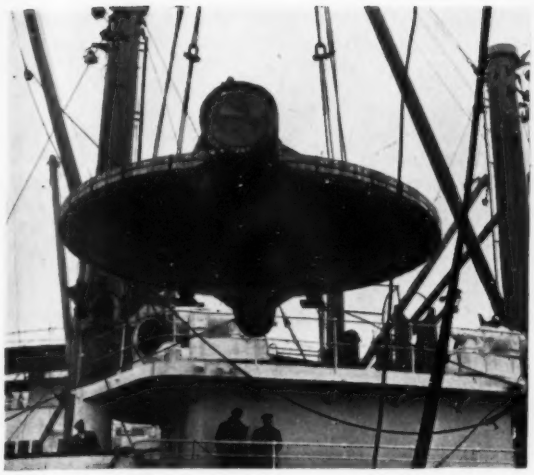


Fig. 1. Glenfield 14 ft. 6 in. diameter butterfly valve erected in the makers' works



Figs. 2 and 3. Views taken during the shipment of the second valve at Glasgow docks

conditions with the full head developing on the inlet side and virtually atmospheric pressure on the outlet side, it is not usual for valves for this duty to operate fully under unbalanced conditions; consequently the bypass valves are used to flood the spiral casings to equalise the upstream and downstream pressures before the main valves are opened. This sequence of operation is entirely automatic, following the starting of the bypass control valves. The opening of the main valves returns the bypass valves to their closed positions, ready for the next opening cycle.

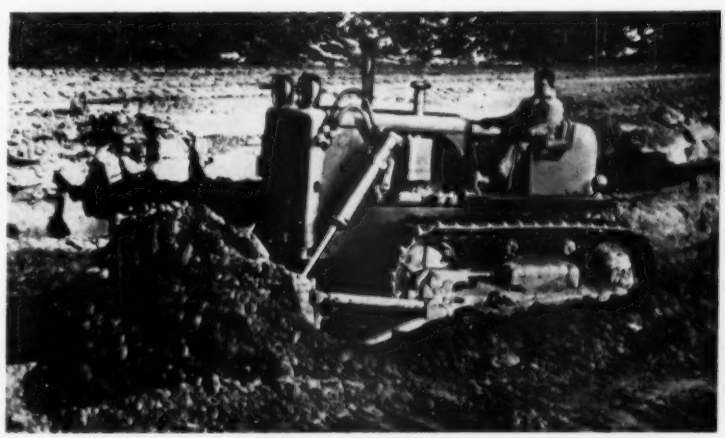
Fig. 1 shows a valve erected in Glenfield & Kennedy's works, and Figs. 2 and 3 were taken during the shipment of the second valve at King George V Dock, Glasgow. The size of the valves necessitated their parts being off-loaded from road-transport vehicles by a mobile floating crane and taken by this vessel down the dock to the seaward side of the cargo ship, the normal dockside crane facilities being unsuitable for their handling.

New International Harvester Crawlers

International Harvester Export Company of Chicago has just announced the introduction of its newest and most advanced-engineered diesel crawler tractor line, comprised of the International TD-6, TD-9, TD-14 and TD-18. Principal engineering changes in these new models are substantially increased horsepower ratings in the TD-6, TD-9 and TD-14; streamlined functional styling; new operator visibility and comfort; pressurised cooling system; and all-weather, positive, easy-starting petrol-conversion systems.

The International TD-6 crawler tractor now is rated at 41·5 drawbar and 50 net engine h.p. Matching the increase in horsepower output is a strengthened power train. Our readers will recall that the British made BTD-6 was announced at a similar advanced rating in our July issue last year.

The International TD-9 crawler tractor now has 54·5 drawbar h.p. and net engine horsepower increased to 66. The TD-9 uses the new Cerametallic clutch facings. This clutch facing is composed of heat-resisting material similar to that used as brake linings on jet aircraft. It is claimed the clutch now gives more rapid and positive engagement with new heat-resisting, and power-holding characteristics. As on the TD-6, operating controls are readily accessible and easy on the operator. The new fold-over seat provided on the TD-6 crawler facilitates the servicing of steering clutch assemblies. On the



International TD-18 with hydraulic bullgrader

model TD-14, the drawbar horsepower has been increased to 78·5 and net engine h.p. has been raised to 95. This increase in horsepower makes the TD-14 the most powerful crawler tractor in its size class. Like the TD-9, the TD-14 has Cerametallic clutch facings, better operating facilities, new hydraulic steering clutch boosters and streamlined appearance. A new heavy-duty swinging-door type radiator guard for mounting direct-lift equipment and 500-hour track roller seals are standard.

The most outstanding engineering changes on the popular TD-18 are new 500-hour track roller seals, swinging-door type radiator guard, and improved streamlined appearance. International's fast petrol-conversion, electric starting system is provided as standard equipment. The TD-18, also featuring as standard equipment the Cerametallic clutch, with other design features that are pointed to lowering maintenance costs. Hydraulic steering clutch boosters are provided and lubrication of the steering clutch assemblies has been centralised. The TD-18 produces 124 h.p. at 1,450 r.p.m. and the drawbar pull is 24,300 lb. Drawbar h.p. is 103, which moves the TD-18 well up within the big crawler tractor class.

Abstracts from the World Technical Press

Plugging the St. Lawrence

Long Sault Dam, included in the first major contract awarded on the St. Lawrence power project by the Power Authority of the State of New York, is located between the mainland of the New York State and the western tip of Long Sault Island. The St. Lawrence River is split by this island into two arms: the north or main channel, known as Long Sault Rapids, and the south channel or Little Sault, which is smaller but also carries a sizeable and fast flow. As the dam actually closes Little Sault at its western end, the contractors, the Dravo Corporation, Pittsburgh, tackled the job in accordance with the following schedule: (1) Excavate across the " neck " of the island a cut 1,600 ft. long by 230 ft. wide to divert the flow of the Little Sault into the North Channel, leaving however an earth plug at either end. (2) Build a 430 ft. bridge on steel sheetpile cells across the cut, to give access to the tip end of the island. (3) Remove the earth plugs from the cut. (4) Divert the flow of the Little Sault into the cut by means of an eight-cell cofferdam. (5) Build the downstream cofferdam to protect the dam site. The final stages were dewatering and excavating. While the cut was being excavated, cells of the upstream cofferdam were constructed, two adjoining each shoreline, thus narrowing the width of the channel to 265 ft. The most difficult operation was, of course, the blocking of the South Channel in order to divert the flow into the cut, and this problem was solved effectively by means of a unique rock-filled timber crib and sled arrangement which cut off the flow and enabled a conventional sheetpile cellular cofferdam to be set up. The steel sled was fabricated on the mainland shore, and carried at each end cribs 19 ft. wide, 45 ft. long and 24 ft. high, designed to hold approximately 1,000 tons of rock to ballast the structure midstream in the fast water. Once fitted on to the sled runners, the cribs left a 60 ft. opening between them which formed the final closure gap. Because of the steep bank on the mainland side, the front half of the sled-crib was built first, and then moved 50 ft. into the river while the rear half was fabricated and attached, whereupon the whole 150 ft. long contraption was pulled over the rocky river bottom to its design location in the deepest section. This was done easily by means of diesel cranes mounted on the island, which, through sets of blocks attached to 100 ton deadmen, pulled cables fastened one each to the three 24 in. sled runners. Lateral drift of the sled was checked by a 1¼ in. diameter cable leading upstream from the forward corner through blocks to a bulldozer, while, at the rear, a drag cable prevented the structure from sliding too fast down the icy riverbank. Once in position, its landward crib was filled with rock and acted as a platform for a crawler crane which could reach across and fill the other crib. The cables were then removed and work began on a dike between No. 8 cofferdam cell and the crib on the island side of the sled. With fabricated screens in place between the uprights on the sled, rock dumped into the last 60 ft. gap made short work of closing off the river channel, and the quiet pool behind the completed dike made pile driving possible for the remaining four cells of the cofferdam, as flow passed under the bridge and through the diversion cut. A detailed description of the crib-sled is given. (E. L. Weidner, *Engineering News-Record*, Vol. 156, No. 10, March 8, 1956, p. 47, 3 pp., 5 ff.)

Note.—See WATER POWER, April 1956, p. 134, and May 1956, p. 184. Long Sault Island is showing at the top of Fig. 4, p. 137, near the left-hand corner.

Driving the Trevallyn Tunnel

This is the power tunnel of the Trevallyn plant, on the Tamar, which supplies Bell's Bay aluminium works, built on the right bank of the estuary. This development of the Hydro-Electric Commission of Tasmania was decided after the old Duck Reach power station, taken over by the Commission from the Launceston City Council in 1944, had proved unable to meet the increasing requirements of the Australian Aluminium Commission. (See WATER POWER, September 1953, pp. 325 and 328). Following a description of the works, the author explains the tunnelling methods applied and gives a detailed account of the construction work and of the difficulties encountered. After it had been assumed that the rock through which the tunnel was driven would require no reinforcement, lining, to a very large extent in the shape of concrete horseshoe frames, had to be resorted to in more than a third of the overall length (two miles). Actually, the Glen Dhu Fault gully had to be negotiated by a steel siphon over 700 ft. in length, so that the tunnel proper is divided into two sections. The intake structure, about 280 ft. long, stands slightly upstream of the dam erected by the Commission, and the tunnel diverts a discharge of 3,000 cusecs from an overall head of 430 ft. The first of the four 27,600 h.p. generating units has

been in operation since May 1955. The contract for the tunnel and ancillary works had been awarded in 1950 to two associated French firms of contractors, the Compagnie Industrielle des Travaux (Entreprises Schneider) and Entreprise Fougerolle pour Travaux (Publics). (G. Le Bel, Directeur Général C.I.T., *Construction*, Vol. XI, No. 3, Mar. 1956, p. 67, 12 pp., 19 ff.)

Cathodic Protection Tests

The cathodic protection studies made by the Rock Island District, North Central Division of the Corps of Engineers, are reviewed and discussed. These investigations are still in progress at Lock and Dam No. 15 on the Mississippi River at Rock Island, Illinois, and at a few other similar structures. The principal conclusion arrived at to date is that corrosion of immersed steel structures that can be made accessible for painting only by expensive unwatering procedures often can be mitigated more economically by cathodic protection than by other means. The finding applies chiefly to the mitre gates and sector gates of navigation locks. The studies indicate further that the exterior and interior surfaces of tainter and roller gates subject to fresh water exposure generally can be protected at lower cost with paint coatings than by cathodic methods. (F. W. Shanks & J. L. Rohwedder, *Engineering News-Record*, Vol. 156, No. 11, March 15, 1956. p. 33, 3 pp., 3 ff.)

Pieve Di Cadore Dam

In addition to a description of this important structure of the Piave River development, of its ancillary works and the construction plant, this article reviews the methods of construction applied, the characteristics of the installations, the measures taken to ensure imperviousness and other features of interest. The results of the concrete and cement tests effected in connection with the Piave-Boite-Vajont works are analysed in an appendix. (Dott. Ing. Mario Pancini, *L'Energia Elettrica*, Vol. XXXIII, No. 1, January 1956, p. 1, 32 pp., 36 ff.)

Testing a Pelton Wheel by Radiography

An account is given of the tests carried out at the Brown-Boveri radiographic laboratory in Baden, Switzerland, on a Pelton wheel by means of betatron rays. The electron accelerator used was of the dual-beam type made by the Brown-Boveri Works. The Pelton wheel tested was intended for a turbine of the Åbjöra plant in Norway. A previous ultrasonic test had failed to detect any faults, but Boving & Co. Ltd., London, who were responsible for the turbine, insisted on a radiographic examination of the heavily stressed parts of the wheel, in compliance with the required acceptance tests. The Brown-Boveri betatron with its 31 MeV radiation has proved particularly well suited to the testing of very thick steel. In this instance, the radiographs revealed that the Pelton wheel was virtually free from defects. Slight lack of homogeneity was detected underneath two of the buckets but as it occurred outside the zone of maximum stress, it was considered negligible. The tests are described. It is claimed that betatron rays produce more reliable and much quicker results than cobalt-60 isotopes in testing very thick steel components. The tests instanced, which required over 100 radiographs, were completed in four days; with cobalt-60 rays, which have a much lower penetrating capacity than the 31 MeV betatron, the same range of tests would have taken a year. (R. Wideröe, *The Brown Boveri Review*, Vol. 42, No. 11/12, November-December 1955, p. 478/480, 2 ff. including reproduction of colour photograph on front page.)

Wallpack Bend Project

Following the recent release of an engineering report, details are given of this multi-purpose Delaware River development. Water supply is the primary objective, flood control, recreational value and power generation following in importance. The dam would consist of a concrete gravity section 1,850 ft. long and 170 ft. above bedrock, plus a 850 ft. long earth section; the reservoir would extend 26 miles in length and the water surface would cover an area of 8,700 acres. Release of water would be controlled by a spillway section incorporating 17 tainter gates 25 ft. high by 40 ft. wide each. A 22,000 kW plant is included in the $69 million initial cost estimate. (*Engineering News-Record*, Vol. 156, No. 9, March 1, 1956, pp. 28/29, 1 f.)

Littleton Project

Together with its sister Comerford development, just downstream, this new Connecticut River development will constitute the largest power station in New England. The dam, 3,150 ft. in overall length along its axis, contains a rolled earth section 2,040 ft. long and 180 ft. high, starting on the Vermont side and retained by a massive 120 ft. high wall on ledge above the New-Hampshire bank. Beyond this, in line, are a concrete non-overflow section 115 ft. long in which final closure was made, a 255 ft. long intake structure, and a 373 ft. spillway section comprising skimmer gate, two bays of stanchion flashboards, three tainter gates, and another two bays of flashboards. Finally there is a concrete non-overflow section 120 ft. long, tying into a 350 ft. earth section. The indoor power house has unusual features, control room, offices, and station service being located below generator level, thereby reducing superstructure requirements to a minimum. The four single-runner Francis turbines, equipped with Woodward-twin-cabinet governors, will each drive a 39,000 kVA umbrella-type vertical generator. The first generator was to be put on the line this spring. (*Engineering News-Record*, Vol. 156, No. 9, March 1, 1956, p. 35, 3 pp., 6 ff.)

Double-Jet Energy Dissipator

This article, printed in French and English, contributed by two Indian specialists, describes their double-jet dissipator and gives an account of the tests, carried out on models of the Bhakra dam outflow spillway, which led to its development. Proceeding from tests effected with a free-discharge bucket, the single deflector was subsequently replaced by the combination of an upper and a lower deflector, and the tests were repeated with various patterns of the troughs and crests of the upper deflector, and at various positions of the lower deflector. It is claimed that this new type of energy dissipator affords a better protection against scouring at the toe of overflow spillways of high dams and other high-head hydraulic structures, and since its working and action are independent of

the tail-water level, that it can be particularly useful when operating in conjunction with high-head structures erected on rivers subjected to a rapid rise and fall of flood levels. (H. L. Uppal and Gajinder Singh, *La Houille Blanche*, Vol 11, No. 1, January-February 1956, p. 8, 15 pp., 15 ff. English Digest p. 6.)

Raft Foundation

A raft or mat foundation covers the entire area beneath a structure and supports all the walls and columns on a combined footing. Wherever building loads are so heavy, or admissible soil pressure so small that the individual footings would cover more than half the building area, a raft foundation is likely to prove more economical. This applies particularly to the structures of hydro-electric stations included in the canal fall projects of the Indus River basin. In the Indus plain no rock is to be found at any reasonable depth, pile foundation is out of the question, and the only alternative is the raft foundation resting on sand layers; this is however feasible only on uniform, well compacted sand layers which must be situated so as to remain permanently under the subsoil water table. The various technical aspects of raft foundations which have been proposed to carry the superstructures of hydro-electric power houses are surveyed and discussed. (Barkat Ali Luna, *Engineering News*, Lahore, Vol. 1, No. 1, February 1956, p. 56, 5 pp., 6 ff.)

Stream Bed Intakes

A team of engineers of Electricité de France gives a comprehensive report on some of the stream-bed structures set up to supplement the main intakes of the Arvan and Aussois developments in the Savoy Alps. These secondary intakes, built on torrents high up in the mountains at hardly, if at all, accessible spots, operate under the most difficult conditions imaginable. Considered individually, they would seem to be of little importance, but taken together within the frame of the hydro-electric scheme to which they are attached, their additional supply of power water to a plant cannot be neglected. In the first section of the report two Arvan and five Aussois stream-bed intakes are briefly described. In principle, they consist primarily of a pit excavated in the bed of the torrent at a convenient spot and protected by a screen set at an adequate slope; in the instance of the Letta intake (Aussois development), a natural hollow in the bed of the torrent provided a ready-made pit which required only a straightening and trimming of the edges to carry the screen. At the Gilbert intake (Arvan development), owing to the heavy blocks of rock carried by the flow, there is no superstructure and all outer works are underground; instead of flowing direct into a channel or tunnel, the water from the intake drops into a 42 m. deep shaft which connects with the main power tunnel. In the second section, the authors review the experience gained from these stream-bed intakes during the first years they have been in service. A reliable knowledge of the liquid and solid discharge of the torrents to be tapped is, of course, a prime necessity when planning the setting-up of a stream-bed intake. The stream bed above the intake must be corrected so as to slow down the flow before it reaches the screens, and to ensure a symmetrical feed of the intake. The shape and spacing of the bars of the screen are discussed. A knife-blade type of bar and a 10 cm. spacing seem to have given the best results. In view of the quantity of sand and gravel passing the intake, flushing is of great importance. Intermittent flushing is to be preferred to the continuous process, particularly in intakes set up at very high altitudes and difficult of access, since it requires less frequent visits of inspection. An attempt at a radical solution of the attendance problem has been made at the Pingon intake (Aussois), where flushing frequency is controlled automatically by a "hydraulic clock" which has given full satisfaction during the two years it has been in operation. This apparatus consists of a cylindrical steel tank fitted with a series of gauged outlets arranged in a spiral around the casing, their number and size varying in accordance with the predetermined ratio of flushing frequency to discharge. These outlets connect with the desanding channel by a pipe which can be bypassed by means of a sluice valve when it is found necessary to open the flushing gate by hand in an emergency. To ensure that the outlets never get blocked up, the bottom section of the tank is fitted with a fine screen which is automatically cleaned at every flushing period by the return flow caused by the fall of the water level in the desilting channel. (X. Ract-Madoux, M. Bouvard, J. Mollet, J. Zumstein, *La Houille Blanche*, Vol. 10, No. 6, December 1955, p. 852, 27 pp., 26 ff., 7 diagrams.)

Plotting Kemano Penstock by Pantograph

At the request of Morrison-Knudsen Company of Canada Limited, a pantograph was used in plotting the cross-section of No. 2 penstock which drops from a tunnel at El. 2,600 ft. at a 48° angle to a short horizontal section at El. 1,600, and then down, again at 48°, to another short horizontal section approaching the power house at El. 210. The penstock was excavated to a nominal 15 ft. in diameter, and the space between the 11 ft. diameter steel lining and the excavation walls is filled with concrete. The pantograph was mounted on a car with its graph chart centred on the longitudinal centreline of the penstock. The procedure applied is briefly described. (*The B.C. Professional Engineer*, Vol. 7, No. 2, February 1956, p. 31, 1 f.)

Pumped Storage

This lecture, given on the occasion of the Centenary of the Swiss Federal Technical University, is devoted to the question of pumped storage, also called in Switzerland artificial or secondary storage. Following introductory paragraphs on reservoirs, firm load and surplus energy, and the possibility of using diesel engines or gas turbines to drive storage pumps, the author reviews the various patterns of pumping units, their couplings, safety devices, and shut-off systems and their control. The possibilities offered by the hydraulic ram are also discussed; extensive tests have been carried out in this respect in Austria, and investigations are also in progress in Switzerland, where there are many hydraulic rams in operation. A hydraulic ram tested at the Institute of Hydraulics of the Federal Technical University attained an efficiency of 35%. The final section of the lecture deals with pump-turbines. An extensive bibliography is appended. (Professor H. Gerber, Federal Technical University, Zurich, *Schweizerische Bauzeitung*, Vol. 74, No. 9, March 3, and No. 10, March 10, 1956, pp. 125 and 139 respectively, 10 pp., 26 ff.)

Dominion Engineering

HYDRAULIC TURBINES

Water power has been a dominant factor in Canada's tremendous modern advance—and over half the water power developed in Canada has been harnessed by Dominion Engineering Hydraulic Turbines.

In Canada and abroad, the Francis, Propeller and Impulse Type Turbines already installed or now under construction at Dominion Engineering amount to a total capacity of nearly 10,000,000 H.P.

The facilities and experience indicated by such a record are at your service anywhere in the world.

Write for General Bulletin No. 201 on Dominion Hydraulic Turbines.

Dominion Engineering Works at Montreal, Canada

DOMINION ENGINEERING
COMPANY LIMITED

MONTREAL, CANADA D CABLE: DOMWORKS

To-day it is essential to be well informed on Commonwealth affairs

NOW, more than ever before, the vast Commonwealth market provides the foundations of Britain's commercial stability. Indeed, it is becoming clear that we can continue as one of the leading trading nations of the World only by developing the resources of the Commonwealth territories to the full.

Self-interest alone should be sufficient to encourage the people of Great Britain to follow closely the life and progress of the other members of this great family of nations. The easiest way of getting news of these events, and, what is just as important, knowing their background is regularly to read the fortnightly publication NEW COMMONWEALTH.

NEW COMMONWEALTH, each fortnight, gives news and a non-partisan survey of current developments in the Industry, Commerce, Agriculture and Government of the many territories which comprise the Commonwealth. It gives detailed reports from able correspondents in every Dominion, Colony and associated territory. It covers every aspect of life and Industry and is of absorbing interest to both layman and specialist.

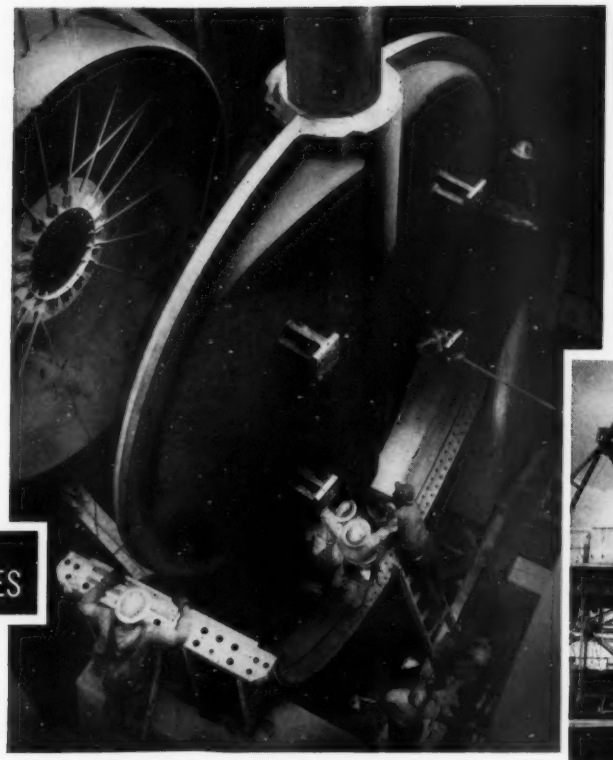
It pays careful attention to the presentation of illustrated articles and pictures which mirror life in the Commonwealth and its pages express the opinions and give the balanced comment of leading authorities on Commonwealth affairs.

It is the journal for the busy man who has time only to consult one source of information and yet who wishes to keep abreast of affairs. A year's subscription costs 50s.

★ **REMEMBER THAT "NEW COMMONWEALTH" IS A MOST EFFECTIVE AND ECONOMICAL ADVERTISING MEDIUM!**

Write for specimen copy:
TOTHILL PRESS LIMITED
33 TOTHILL STREET
LONDON, S.W.1

Building the World's Largest Aluminium Smelter
Dollar-earning Opportunities for British Exporters
Grain Storage in Tropical and Other Climates
UGANDA Strides to the Forefront
Malaya's Twelfth-Hour Chance



An 18' butterfly valve disc is shown here during installation at Blakely Mountain in Arkansas. Note the streamlining of the welded disc.

Photos – Vicksburg District, Corps of Engineers

SMS
BUTTERFLY VALVES

SMS VALVE SEALS CUT LEAKAGE TO MINIMUM

SMS Butterfly Valve seals cut leakage to a minimum. Disc seals are adjustable from either inside or outside, whichever is specified. Specially-developed SMS trunnion seals are essentially drop-tight.

With inside adjustment, the disc may be seated directly on the plate steel housing, as at Blakely Mountain, illustrated above, and as at Fort Peck, Montana. Here a 16 ft. dia. valve, recently tested after 14 years of service, had *less than ½ gpm leakage.*

SMS welded discs and housings assure greater freedom from the material defects of castings and permit more economical construction. The photo illustrates the streamlining possible with welded steel plate construction. This holds head losses and turbulence to a minimum.

SMS has designed and built butterfly valves in diameters from 3 inches to 18 feet, for service with operating heads up to 750 feet. For the assurance that your hydraulic equipment will meet or exceed specifications, you can rely on over three-quarters of a century of experience that SMS offers. For full information on butterfly valves, hydraulic turbines and accessories, write S. Morgan Smith Company, York, Pennsylvania.

Hydraulic Turbines
Pumps
Gates & Hoists
Trash Rakes
Accessories

HYDRODYNAMICS

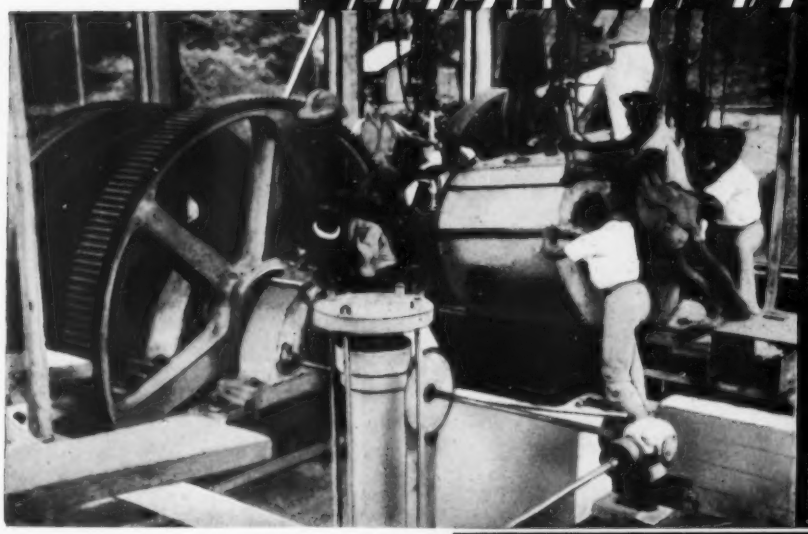
Rotovalves
Ball Valves
Butterfly Valves
Free-Discharge Valves
Controllable-Pitch Ship Propellers

S. MORGAN SMITH

AFFILIATE: S. MORGAN SMITH, CANADA, LIMITED, TORONTO

Licensees: The Harland Engineering Company, Ltd., Alloa, Scotland
Tokyo Shibaura Electric Co., Ltd., Japan

EFFICIENT HAULAGE



Hydro-Electrification Scheme—Ceylon

Installation of Haulage Gear at Norton Bridge

M. B. WILD & CO LTD NECHELLS BIRMINGHAM 7

Telephone: EAST 2041-7

Telegrams & Cables: HAULING BIRMINGHAM 7

WATER POWER

SUBSCRIPTION ORDER FORM

Beginning with the next issue please post your Journal monthly for one year.

NAME .....

ADDRESS .....

.....

Subscription Rate is 35s. per annum post free

33 TOTHILL STREET, WESTMINSTER, LONDON, S.W.1

For Hydraulic Plants we supply

Steel Castings
plain carbon steel
up to 400 tons

13 % Cr and else
alloyed steel
up to 120 tons
cast weights

Steel Forgings
plain carbon
and alloyed steel
up to 150 tons
ingot weight

BV-Vacuum Steel
for complicated
and highly stressed
castings or those
exposed to cavitation
and for highly
stressed forgings

Postbox 325, Bochum (Germany) · Telephone 69021 · Telegrams: Gusstahl · Teleprinter: Gusstahl 0825831

Gusstahlwerk Bochumer Verein Aktiengesellschaft BOCHUM

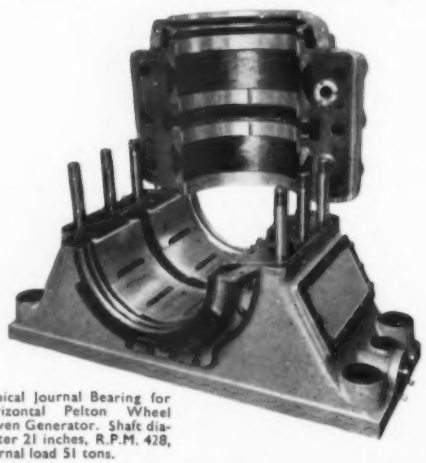
PIPELINE FOR GRUDIE BRIDGE HYDRO-ELECTRIC SCHEME

supplied and erected by

MECHANS LIMITED

PIPELINE AT GRUDIE BRIDGE.
Reproduced by kind permission of the North of Scotland Hydro-Electric Board.

SCOTSTOUN IRON WORKS GLASGOW W.4



Typical Journal Bearing for horizontal Pelton Wheel driven Generator. Shaft diameter 21 inches, R.P.M. 428, Journal load 51 tons.

MICHELL BEARINGS

The original pivoted pad film lubricated bearings. They carry loads with complete reliability and efficiency with downright simplicity for all Hydro-Electrical installations, and for Marine, Mining, Paper-Making Machinery and other requirements.

MICHELL BEARINGS LTD.
SOUTH BENWELL NEWCASTLE UPON TYNE 5
Telephone 34279 Telegrams : MICHBEARO, NEWCASTLE

Racks and Rack Cleaning Machines for:
—water-intakes for power plants
—pumping stations
—water purification plants

Engineering Works JONNERET S.A.
Geneva (Junction), Switzerland

a specialist job

by **MILLARS'** *of course*

This Thames-side excavation—to a depth of 28 feet in gravelly sand—at the Albert Embankment (by Messrs. Wates of Norbury for the National Dock Labour Board) was made possible by the use of Millars' Wellpoint Dewatering System, a site drying method which avoided all danger of subsidence and consequent collapse of road and adjoining buildings.

Write for further details to :—

MILLARS' MACHINERY COMPANY LTD.,
Thorley Works, Bishop's Stortford, Herts. *(Tel. Bishop's Stortford 694/5. Grams: Millars, Bishop's Stortford.)* Wellpoint Department: Cromford House, Cromford Court, Manchester 4. *(Tel: Blackfriars 8813/4. Grams: Milamix, Manchester).* London Office: Pinners' Hall, Great Winchester Street, London, E.C.2. *(Tel: London Wall 4266-9, 4260 and 1521-5. Grams: Milamix, Stock, London).*
IN ASSOCIATION WITH FOUNDATION EQUIPMENT CORPORATION OF AMERICA, WE COVER THE WORLD.

ELECTRIC DERRICK CRANES

Some Outstanding Features:

- **PROGRESSIVE DESIGN TO B.S.S. 327/1**
- **EXCLUSIVE "UNIT" GEARING**
- **SUPERIOR VISIBILITY**
- **HIGH SPEED OPERATION**
- **RELIABILITY AND ECONOMY**
- **INTERCHANGEABLE SPARES**

LONDON OFFICE: Finsbury Pavement House, 120 Moorgate, E.C.2
Tel.: MONarch 4629

7-ton Electric Derrick Crane x 120 ft. Jib

Phone: CARNOUSTIE 2214-5

ANDERSON

THE ANDERSON-GRICE CO. LTD.
TAYMOUTH ENGINEERING WORKS, CARNOUSTIE, SCOTLAND

Grams: "DIAMOND" CARNOUSTIE

INDEX TO ADVERTISEMENTS

A

A.C. Plant & Hire Co. Ltd., The ... ... —
Acciaieria E Tubificio Di Brescia ... ... —
Allgemeine Elektricitäts-Gesellschart 45
Allis-Chalmers Manufacturing Co. ... ... —
Allmanna Svenska Electriska Aktiebolaget 35
Aluminium Wire & Cable Co. Ltd. 50
Anderson Grice, The Company, Ltd. 73
Andritzer Maschinenfabrik ... ... —
Ansaldo San Giorgio, S.p.A. ... ... Inside Back Cover
Armfield Hydraulic Engineering Co. Ltd. 38
Ateliers de Constructions Electriques de Charleroi —
Atlas Copco A.B. 22, 23, 24, 25

B

Balfour, Beatty & Co. Ltd. ... ... —
Bell, Theodore & Co. Ltd. ... ... —
Birkett, T. M., Billington & Newton Ltd. ... ... —
Birtley, The Co., Ltd. 58
Bochumer Verein 71
Bouchayer & Viallet ... ... —
Boving & Co. Ltd. 5
British Insulated Callender's Cables Ltd. 66
British Pitometer, The, Co. Ltd. ... ... —
British Ropeway Engineering Co. Ltd. ... ... —
British Thomson-Houston Co. Ltd. 56
Brown, Boveri & Co. Ltd. 6
Bruce, Peebles & Co. Ltd. 12
Bucyrus-Erie Co. 31
Bullers Ltd. 19
Buss, A.G. 10
Butters Bros. & Co. Ltd. 42

C

Canadian Vickers Ltd. ... ... —
Ceretti & Tanfani Ropeway Co. Ltd. ... ... —
Charmilles Engineering Works Ltd. ... ... —
Compagnia Generale di Elettricita ... ... —
Compagnie Industrielle de Travaux ... ... —
Consolidated Pneumatic Tool Co. Ltd. 4
Costain, Richard, Ltd. ... ... Inside Back Cover
Craelius Co. Ltd. ... ... —
Crompton Parkinson (Export) Ltd. 54
Czechoslovak Chamber of Commerce 44

D

de Roll, Louis, Ironworks Ltd. 3
Distington Engineering Co. Ltd. ... ... —
Dominion Engineering Co. Ltd. 67
Dortmunder Union Bruckenbau A.G. ... ... —
Drees & Co., G.m.b.H. 13
Dresser Manufacturing Division 47

E

Eimco (Gt. Britain) Ltd. ... ... —
ELIN, A.G. 36
English Electric Co. Ltd. ... ... Outside Back Cover
Escher Wyss Ltd. ... ... —

F

Ferguson Pailin Ltd. ... ... —
Ferranti Ltd. 43
Ferrum (England) Ltd. 29
Fischer, Ltd., George ... ... —

G

Galileo Officine di Battaglia Terme ... ... —
General Electric Co. Ltd. 30
Gilbert Gilkes & Gordon Ltd. 51
Giovanola Freres, S.A. 20
Glenfield & Kennedy Ltd. 18

H

Hackbridge & Hewittic Electric Co. Ltd. 28
Harland Engineering Co. Ltd., The 64
Henderson, John M. & Co. Ltd. 46
Henley's, W. T., Telegraph Works Co. Ltd. ... 60
Hitachi Ltd. 16
Holman Bros. Ltd. 7
Huhn, C. 62

I

Ingersoll-Rand Co. Ltd. ... ... —
International Engineering Co., Inc. 52

J

Jonneret, S.A. 72

K

Karlstads Mekaniska Werkstad, Akt. 37
Kuljian Corporation, The ... ... —
Kvæner Brug. A.S ... ... —

L

Leffel, James & Company, The 59
Le Materiel Electrique, S-W ... ... —

M

Magrini, S.p.A. ... ... —
Maier, B., Maschinenfabrik ... ... —
Marelli, Ercole & Co., S.p.A. ... ... —
Mechans Ltd. 72
Metropolitan-Vickers Electrical Co. Ltd. ... Front Cover
Michell Bearings Ltd. 72
Millars Machinery Ltd. 73
Mitchell Construction, The Co. ... ... —

N

Neyrpic 14
Newport News Shipbuilding & Dry Dock Co. ... 63
Nuttall Edmund Sons & Co. (London) Ltd. ... —
Nydqvist & Holm, A/B ... ... —

O

Oerlikon Engineering Company ... ... —

P

Painter Bros. Ltd. 17
Pellizari, A., & Figli, S.p.A. ... ... —
Pirelli-General Cable Works Ltd. 49
Pohlig, J., A.G. 41

R

Ransomes & Rapier Ltd. ... ... —
Reyrolle, A. & Co. Ltd. ... ... Inside Front Cover
Riva, Costruzioni Meccaniche ... ... —
Ruston-Bucyrus Ltd. 31
Ruston & Hornsby Ltd. ... ... —

S

S. A. Ateliers De Secheron 32
SACE Costruzioni Elettromeccaniche ... ... —
Salvi, A. & Co. 15
Salzsgitter Maschinen Aktiengesellschaft ... ... —
Scarpa & Magnano 61
Siemens-Schuckertwerke, A.G. 9
Siemens & Halske, A.G. ... ... —
Smith, A. O. Corporation ... ... 26 & 27
Smith, Fredk. & Co. ... ... —
Smith, S. Morgan, Company ... ... 33 & 69
Smith, Thos. & Sons (Rodley) Ltd. ... ... —
Societa Anomina Elettrificazione, S.p.A. 11
Soc. p. Az. Cementi Armati Ing. Mantelli 39
Societe des Forges et Ateliers du Creusot ... ... —
Societa Condotte Forzate 48
Societa Elettro-Morsetterie Volpato ... ... —
Societa Nazionale Delle Officine Di Savigliano ... ...
Societe Dauphinoise d'Etudes et de Montages ... —
South Durham Iron & Steel Co. Ltd. ... ... —
Standard Telephone & Cables Ltd. ... ... —
Steatite & Porcelain Products Ltd. 34
Storey, Thos. (Engineers) Ltd. 8
Sulzer Bros. (London) Ltd. ... ... —
Svenska Metallverken A/B ... ... —

T

Taylor Tunnicliff & Co. Ltd. ... ... —
Technoexport 40
Tees Side Bridge & Engineering Works Ltd. ... —
Tokyo Shibaura Electric Co. Ltd. ... ... —
Torno, G. & C. ... ... —
Tosi, Franco, S.p.A. 55

V

Vevey Engineering Works Ltd. 53
Voith, J. M., G.m.b.H. 57
Voith, J. M. (St. Pölten) ... ... —

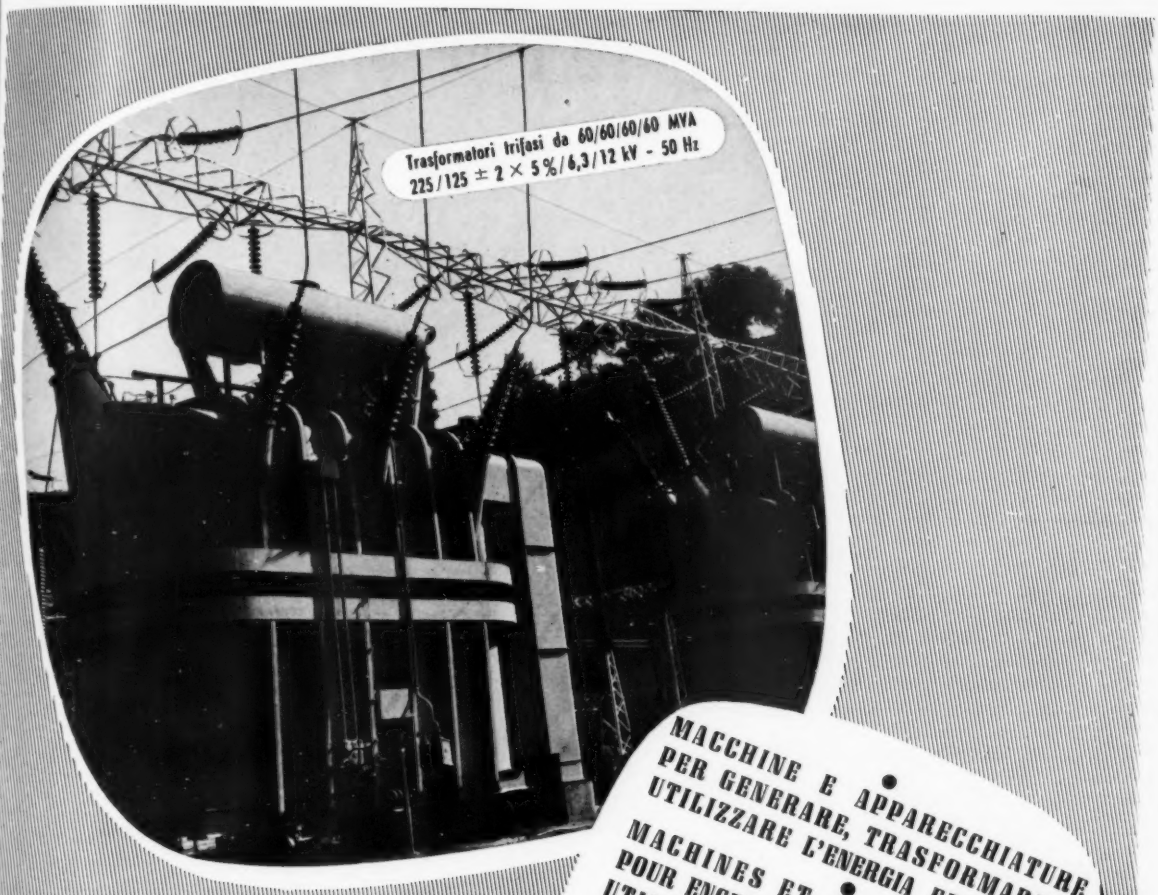
W

Waagner Biro ... ... —
Wailes Dove Bitumastic Ltd. ... ... —
Wild, M. B. & Co. Ltd. 70
Wood, Hugh & Co. Ltd. 21
Wykeham, W. & Co. Ltd. ... ... —

Y

Yorkshire Electric Transformer Co. Ltd. ... ... —

LONDON: Published by TOTHILL PRESS LIMITED, Proprietors of WATER POWER, at 33 Tothill Street, Westminster, S.W.1. and Printed by W. & H. SMITH LTD., Evesham, Worcestershire. *July, 1956.*



MACCHINE E APPARECCHIATURE PER GENERARE, TRASFORMARE E UTILIZZARE L'ENERGIA ELETTRICA

MACHINES ET APPAREILLAGES POUR ENGENDRER, TRANSFORMER ET UTILISER L'ÉNERGIE ÉLECTRIQUE

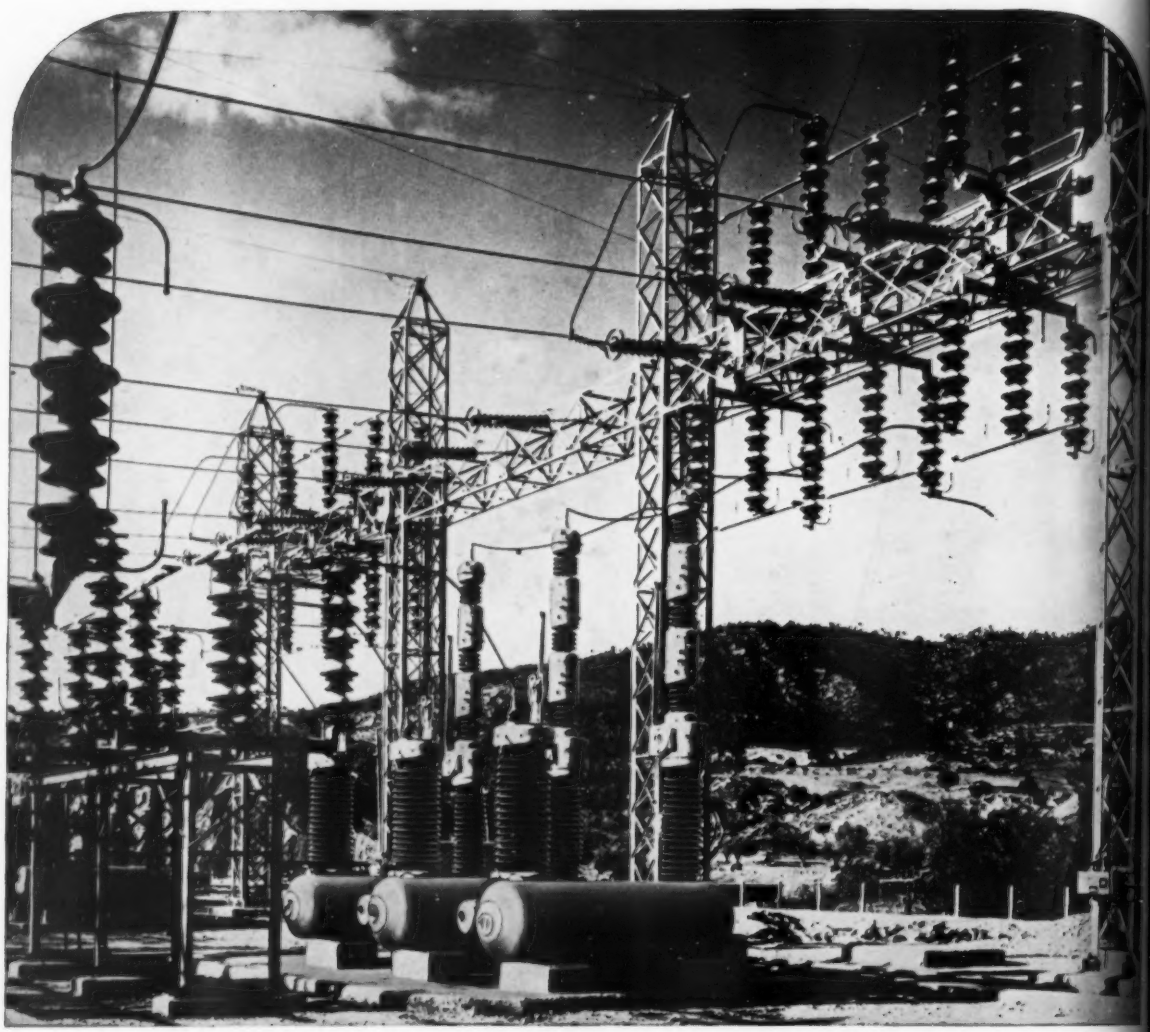
MACHINES AND EQUIPMENT FOR GENERATING, TRANSFORMING AND UTILISING ELECTRIC POWER

MASCHINEN UND AUSRÜSTUNGEN ZUR ERZEUGUNG, UMFORMUNG UND AUSNÜTZUNG VON ELEKTRISCHER ENERGIE

ASG

ANSALDO-SAN GIORGIO
GENOVA

GENOVA (ITALIA) - MURA DI SANTA CHIARA, 1 - TELEFONO: 586.741 TELEGRAMMI: SERAS-GENOVA



One of twelve 150 kV air-blast circuit-breakers, frame 'g', at the Cofrentes hydro-electric generating station of the Hidro-Eléctrica Española, fitted with additional air receivers for high-speed auto re-closing.

Air-blast circuit-breakers

Voltage ratings up to 330 kV • Current ratings up to 1200 amperes

Breaking capacities up to 15,000 MVA

'ENGLISH ELECTRIC'

switchgear

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Switchgear Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

SGS.18A.